**Evaluating Loneliness Measurements across the European Union**

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**We wrote this registered report in the past tense to avoid errors when completing the Stage 2 Registered Report.**

**Author note:** Béatrice d’Hombres and Elizabeth Casabianca have reviewed the data before the submission of this Registered Report. The final decisions for data analysis, hypothesis, and inferences are all with Bastien Paris, Miguel Silan, Ivan Ropovik, and Hans IJzerman. Paris, Silan, Ropovik, and IJzerman did not have access to the full data prior to In Principle Acceptance. They received data for the exploratory fold from Casabianca, who kept the confirmatory fold until after In Principle Acceptance.

**Abstract**

Loneliness has been associated with several detrimental effects for individuals and societies, making it a priority for monitoring across the European Union. While many loneliness measures currently exist, notable gaps exist regarding knowledge of their psychometric structure, reliability, comparability, and validity, particularly as it pertains to their suitability for EU-wide population surveys. Relying on data from the *EU Loneliness Survey* covering the 27 EU member states (*N*=25,646), we examined the factor structure, internal consistency, measurement invariance, and construct validity of the six-item De Jong Gierveld Loneliness Scale (DJGLS-6), the three-item UCLA Loneliness Scale (T-ILS), and a single-item measure of loneliness. Following a process of pre-registered analyses in an exploratory fold, followed by pre-registered confirmatory analyses testing the model sharpened in the exploratory fold, we found (a) the DJGLS-6 to show [poor/acceptable/very good] fit to a [one/two] factor structure for XX countries, [sufficient/insufficient] internal consistency for XX countries, [measurement invariance property described here], and [sufficient/insufficient] construct validity for XX countries, (b) the T-ILS to show [poor/acceptable/very good] fit to a one factor structure for XX countries, [sufficient/insufficient] internal consistency for XX countries, [measurement invariance property described here], and [sufficient/insufficient] construct validity for XX countries, and (c) the single-item measure of loneliness to show [sufficient/insufficient] construct validity for XX countries. Overall, the evidence suggests [based on the results described above, we will conclude on the suitability of the DJGLS-6, T-ILS, and single-item measure for monitoring loneliness in the European Union].

**Keywords:** loneliness; measurement; inventory; measurement properties, European Union.

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| **Question** | **Hypothesis** | **Sampling Plan** | **Analysis Plan** | **Rationale for deciding the sensitivity of the test for confirming or disconfirming the hypothesis** | **Interpretation given different outcomes** | **Theory that could be shown wrong by the outcomes** |
| Is the model fit sufficient for a) the DJGLS-6, and b) the T-ILS across the European Union? | Following analyses on the exploratory fold, we expect the DJGLS-6 to provide a sufficient fit to a two-factor structure for 14 countries, and the T-ILS to provide a sufficient fit for a one-factor structure for 25 countries (Appendix A). | We will partition the data from the EU Loneliness Survey (*N* = 25,646, covering the 27 EU member states) into separate exploratory and confirmatory folds of similar sizes (approximately 500 participants per country and per fold). We will stratify the data to ensure similarities in terms of countries between folds. Upon completion of the analyses on the exploratory fold, we will formulate hypotheses based on the obtained results, then test them on the confirmatory fold.  Elizabeth Casabianca, who is not involved in drawing inferences from the analyses, will supervise the splitting of the folds. | We will assess the factor structure of the DJGLS-6 and T-ILS using confirmatory factor analysis on the factor structures identified in the exploratory fold, for each country separately. | A sample size of n=500 per country and fold has been found to be the minimum ideal number of participants for factor analyses under various conditions (MacCallum et al., 1999). | We applied the same criteria as in exploratory fold: We evaluated the fit as acceptable (sufficient) with Comparative Fit Index (CFI) values ≥ .90 and Root Mean Squared Error of Approximation (RMSEA) values ≤ .08, and as very good with CFI values ≥ .95 and RMSEA values ≤ .06 (De Roover et al., 2022; Hu & Bentler, 1999).  In case the conclusion regarding the adequacy of model fit converges, we will consider the analyses in the confirmatory fold a successful replication.  In case the model fit obtained from confirmatory factor analyses does not reach an acceptable level, we will consider the measure to be inadequate for the proposed factor structure. | If the model fit for either scale in a country is poor, it means the concept does not map onto the measure as theorized. In that case, we will make recommendations for those countries on how to develop new measures. |
| How high is the internal consistency of a) the DJGLS-6, and b) the T-ILS across the European Union? | Following analyses on the exploratory fold, we expect the DJGLS-6 to demonstrate sufficient internal consistency for 24 countries, and the T-ILS to demonstrate sufficient internal consistency for the 27 countries (Appendix A). | We will partition the data from the EU Loneliness Survey (*N* = 25,646, covering the 27 EU member states) into separate exploratory and confirmatory folds of similar sizes (approximately 500 participants per country and per fold). We will stratify the data to ensure similarities in terms of countries between folds. Upon completion of the analyses on the exploratory fold, we will formulate hypotheses based on the obtained results, then test them on the confirmatory fold.  Elizabeth Casabianca, who is not involved in drawing inferences from the analyses, will supervise the splitting of the folds. | We will assess the internal consistency of the DJGLS-6 and T-ILS by computing McDonald’s ω.  We will report the ω unidimensional in case of a one-factor structure, or the ω hierarchical in case of a n-factors structure. | No clear guidelines exist regarding sample size requirements on internal consistency analyses. However, sample sizes for each country will be larger than a conservative threshold of n=400 proposed by Charter (1999). | We will apply the same criteria as in exploratory fold: We considered ω values ≥ .60 as indicators of sufficient internal consistency for the DJGLS-6 and T-ILS.  If estimates are on the same side of the .6 threshold, we considered it a successful replication.  In case the measure does not have sufficient internal consistency, items within the measure can’t be thought to all measure loneliness. | For both the two subscales of the DJGLS-6 and the T-ILS, if we find insufficient internal consistency for a given country (ω ≥ .60), then we recommend against using that measure for that country. In addition, we will recommend strategies to develop new measures. |
| Are a) the DJGLS-6, and b) the T-ILS invariant across the European Union? | Following analyses on the exploratory fold, we expect the DJGLS-6 to demonstrate scalar invariance across 2 clusters of countries, and the T-ILS to demonstrate scalar invariance across the 27 countries (Appendix A). | We will partition the data from the EU Loneliness Survey (*N* = 25,646, covering the 27 EU member states) into separate exploratory and confirmatory folds of similar sizes (approximately 500 participants per country and per fold). We will stratify the data to ensure similarities in terms of countries between folds. Upon completion of the analyses on the exploratory fold, we will formulate hypotheses based on the obtained results, then test them on the confirmatory fold.  Elizabeth Casabianca, who is not involved in drawing inferences from the analyses, will supervise the splitting of the folds. | We will assess the measurement invariance of the DJGLS-6 and T-ILS using multigroup confirmatory factor analysis on the clusters of countries identified in the exploratory fold. For clusters of countries where at least metric invariance holds, we will further examine whether the given measure exhibits invariant measurement properties across levels of gender (female/male) and age (6 groups). | Again, a sample size of n=500 has been found to be the minimum ideal number of participants for factor analyses under various circumstances (MacCallum et al., 1999) | We applied the same criteria as in exploratory fold. We established configural invariance with the same criteria as for the factor structure property (i.e., CFI values ≥ .90 and RMSEA values ≤ .08);  We established metric and scalar invariance if the corresponding measurement model has ΔCFI value ≥ -.02 or ΔRMSEA value ≤ .03 compared to the subordinate model (i.e., configural or metric, respectively).  In case the same level of invariance across the given clusters of countries is found, we will consider it a successful replication.  If a measure does not reach scalar invariance across countries, factor means cannot be meaningfully compared between these countries, making the measure inadequate for cross-country comparisons. | If scalar invariance is not achieved across EU countries for a particular measure, it could threaten the validity of results in studies investigating differences in loneliness prevalence between countries that do not exhibit invariance with that measure. |
| Does the construct validity of a) the DJGLS-6, b) the T-ILS, and c) the single-item measure of loneliness across the European Union meet the minimum standards set forth?  Specifically, are they significant in the expected direction? It is important to note that our minimum standard permits only minimal theoretical interpretation. This standard does not evaluate the relative effect size between constructs (e.g., social support versus depression). In other words, we will assess whether there is sufficient, though not necessarily sophisticated, construct validity. | Following analyses on the exploratory fold, we expect the DJLS-6 to demonstrate sufficient construct validity for 25 countries, the T-ILS to demonstrate sufficient construct validity for 22 countries, and the single-item to demonstrate sufficient construct validity for 19 countries (Appendix A). | We will partition the data from the EU Loneliness Survey (*N* = 25,646, covering the 27 EU member states) into separate exploratory and confirmatory folds of similar sizes (approximately 500 participants per country and per fold). We will stratify the data to ensure similarities in terms of countries between folds. Upon completion of the analyses on the exploratory fold, we will formulate hypotheses based on the obtained results, then test them on the confirmatory fold.  Elizabeth Casabianca, who is not involved in drawing inferences from the analyses, will supervise the splitting of the folds. | We will assess the three measures’ construct validity through tests of their nomological networks, by reporting bivariate latent correlation coefficients (correlations of factor scores) with various items, for each country separately. | Our sample sizes will be larger than the threshold of n=250 at which correlations appear to stabilize (Schönbrodt & Perugini, 2013). | We applied the same criteria as in exploratory fold. At least two-thirds of the latent correlations obtained have to be significant at the nominal rate of p<0.05 per country for 12 tests (p<0.004 when corrected for multiple comparisons using Bonferroni correction), of magnitude | *r* | ≥ .10, and in the expected direction: positive latent correlation with the indicator of negative emotion, and negative latent correlations with the indicators of social connectedness, positive emotion, and health.  We will apply Fisher's z-transformation to the correlation coefficients from the exploratory and confirmatory fold and will calculate the z-score for their difference. We will then use a BIC approximation (implicitly assuming a unit information prior) to compute Bayes factors (Wagenmakers, 2007) to assess to what degree do the data support the H0 of no difference between the correlations.  We will consider the correlation coefficients to be successfully replicated if either both correlation coefficients are significant, above |r| ≥ .10, and in the same direction, or in case the BF01 (in favor of the null) is larger than 3 (taken as an indication of equivalence of the correlation coefficients).  In case the loneliness measure does not have sufficient construct validity, we will consider the measure to be inadequate for measuring loneliness. | For all measures, insufficient construct validity in a given country would question whether the measure assesses loneliness, and may lead to inaccurate assessments and lack of confidence in results of studies that employ the measure in that country. |

**Evaluating loneliness measurements across the European Union**

Loneliness, the negative experience caused by a discrepancy between one’s desired and achieved social relations (Perlman & Peplau, 1981), has gained massive interest in worldwide politics over the last decade. The World Health Organization (2023) has launched a commission on social connection, the US Surgeon General portrayed loneliness as a public health crisis (Scheimer & Chakrabarti, 2020), both the UK and Japan appointed a minister to address loneliness (Prime Minister’s Office of Japan, 2021; UK Government, 2018), and the European Union’s Commission instituted a research group on loneliness (European Commission, 2022). Such increased attention across countries and organizations underscores the rising importance of strengthening social ties in our societies.

One crucial step in addressing loneliness in the European Union (EU) is understanding it across different countries, languages, and cultures to monitor it accurately and effectively. Accurate and effective monitoring, in turn, relies on measurement meeting various hallmarks of measurement quality both across and within different cultural settings. Many loneliness measures are available in the literature (Maes et al., 2022; Mund et al., 2023), but surprising gaps exist regarding knowledge of their psychometric structure, reliability, comparability, and validity, particularly as it pertains to their suitability for EU-wide population surveys. Relying on data collected in the 27 EU member states, we aimed to fill this gap by providing an examination of the psychometric properties of the three-item UCLA Loneliness Scale (T-ILS; Hughes et al., 2004), the six-item De Jong Gierveld Loneliness Scale (DJGLS-6; De Jong Gierveld & Van Tilburg, 2006), and a single-item measure of loneliness.

**Loneliness’ Impact on EU Citizens and its Measurement**

Loneliness poses substantial societal costs, with studies estimating loneliness to be associated with greater healthcare use and expenditures (Beutel et al., 2017; Gerst-Emerson & Jayawardhana, 2015; Holt-Lunstad et al., 2017). Loneliness impacts health and longevity similar to other clinical risk factors (Holt-Lunstad et al., 2010; Pantell et al., 2013). Research suggests, for instance, that a one-point increase in loneliness is associated with a 26% increased risk of early death consistently across different demographic groups (Holt-Lunstad et al., 2015). Loneliness is associated with cardiovascular disease, hypertension (Hawkley et al., 2010; Valtorta et al., 2016), with a greater decline in activities of daily living and motor performance (Perissinotto et al., 2012; Buchman et al., 2010), and longer use of skilled nursing facility (Pomeroy et al., 2023a).

These impacts on physical health translate to economic costs. In the Netherlands, for instance, loneliness is associated with an increased spending in mental healthcare costs by 11.1% and general practitioner costs by 0.5% (Meisters et al., 2021). Loneliness in Spain is estimated to have a total cost of 14 billion euros per year, accounting for 1.17% of Spain’s Gross Domestic Product (GDP) as of 2021 (Observatorio Estatal de la Soledad No Deseada, 2023). The costs associated with productivity losses are over 8 billion euros per year, approximately 0.67% of the country’s GDP. Loneliness in Spain also leads to a significant reduction in quality of life, equating to a loss of more than 1 million Quality Adjusted Life Years (QALYs), not associated with mortality. Moreover, premature deaths due to loneliness contribute to an annual loss of nearly 18,000 QALYs, indicating that the total loss in quality of life due to loneliness represents 2.79% of the total healthy life years of the Spanish population over 15 years of age. Loneliness thus seems to have significant costs, which may extend across the EU. However, the complexity of measuring loneliness has led to uncertainties regarding the precise relationship of loneliness and various health outcomes.

For example, it is not always clear which of the factors (i.e., social isolation or loneliness) predict health outcomes just as it is unclear what is the direction of causal effects at play. Further, while loneliness is consistently correlated with worse mental and physical health (for reviews, see Hawkley & Cacioppo, 2010; Leigh-Hunt et al., 2017; Park et al., 2020) the impact of loneliness on mortality could be confounded by other factors like socioeconomic status, access to care, and health conditions (Elovainio et al., 2017; Perissinotto et al., 2012). Most studies do not include measures of social isolation and loneliness. Notable exceptions are by Valtorta et al. (2018) who find that loneliness, but not social isolation, increases the risk of heart disease and stroke, while Hakulinen et al. (2018) report both loneliness and social isolation as risk factors. The evidence on the cumulative effect of loneliness on cardiovascular disease risk is equally mixed: Hawkley et al. (2010) and Caspi et al. (2006) suggest a dose-response relationship, but Valtorta et al. (2018) does not. These differences between reports may be due to sampling differences, inaccuracies in statistical reporting, or measurement error.

Perhaps part of the problem of measuring loneliness is conceptual. Loneliness on the one hand and social isolation and exclusion on the other hand, are thought to be distinct constructs (Perlman & Peplau, 1981; Pomeroy et al., 2023b; Prohaska et al., 2020). Loneliness has been defined by some researchers as subjective social isolation (Holt-Lunstad et al., 2015), by others as the negative experience caused by a discrepancy between one’s desired and achieved social relations (Perlman & Peplau, 1981; see also Fried et al., 2020), and sometimes more specifically as inadequate experience to an intimate other person, family and friends, and community life and collective identity and roles (Prohaska et al., 2020).

Loneliness is most-assessed as a general construct (e.g., Russell., 1996), yet researchers have long argued for the multidimensionality of loneliness (Van Tilburg, 2021; Weiss, 1973). Researchers and practitioners alike often distinguish between *social loneliness*, the type of loneliness that arises when a person perceives to lack social resources, and *emotional loneliness*, which arises when a person perceives to lack close emotional attachments (Maes et al., 2022), while loneliness can be acute or chronic. Overall, there is a general consensus in the field for consolidation and consensus of definitions and therefore measurement for loneliness and its related concepts (e.g., Pomeroy et al., 2023b; Prohaska et al., 2020). At the heart of all these issues is the mapping of the concept of loneliness to its measurement. To effectively design and implement targeted interventions and policies for addressing loneliness in the EU, one crucial first step is to evaluate measurement tools for population surveys.

**Measures of Loneliness: Focus on Population Monitoring**

Current-available (short or long-form) measures are likely not suitable to provide policy recommendations. First, correlations between different single-item measures of loneliness and multi-item measures can be as low as .27 (Gallup, 2022). Second, uncertainty around prevalence rates remains. For instance, within the same year (2022), prevalence rates of single-item loneliness estimated by different surveys (the Joint Research Centre [JRC] EU-wide loneliness measurement [which we currently study] and the Meta-Gallup State of Social Connection study; Gallup, 2022) differ – on average – by 4.04 percentage points in 23 EU member states, with some estimates differing by as much as 8 percentage points.[[1]](#footnote-2) Finally, different researchers have vastly different inferences for the same populations in whether loneliness remains stable (Hawkley et al., 2019), decreases in prevalence (Clark et al., 2015; Trzesniewski & Donnellan, 2010), slightly increases in prevalence (Buecker et al., 2021), or increases so rapidly that it can be classified as an epidemic (Scheimer & Chakrabarti, 2020). Measurement error is potentially at the heart of such different inferences.

Measures to assess loneliness in the general population range from single-item measures to multiple-item questionnaires, with various degrees of suitability for population surveys (for recent reviews of loneliness measures, see Maes et al., 2022; Mund et al., 2023), ranging from single-item (e.g., “How much of the time, during the past 4 weeks, have you been feeling lonely”, European Commission, 2018) to composite indexes (e.g., the UCLA loneliness scale; Russell et al., 1978). Single-item measures are cost-effective and under resource constraints, they allow for the measurement of additional latent constructs, encouraging the development and testing of causally more comprehensive, theoretically sophisticated models (Hayduk & Littvay, 2012). They are also easy to deploy for the monitoring of larger populations. However, they come with several disadvantages: The terms “loneliness” or “lonely” are explicitly stated in these measures, making them more vulnerable to social desirability bias for those respondents who perceive stigma surrounding loneliness (Barreto et al., 2022; Kerr & Stanley, 2021; Russell, 1982).

Relatedly, an inherent problem remains for single-item measures to examine several important types of validity evidence. Namely, (1) it is unknowable how tight the link is between the single-item measure and the underlying latent construct of loneliness, (2) we cannot examine how well the latent factor determines the variance in the single-item measure relative to other theoretically equivalent operationalizations of the loneliness construct, (3) in substantive research applications, it is not possible to separate the true loneliness variance from the systematic error due to construct-irrelevant factors and random measurement error, and (4) it is not possible to examine whether the measurement of the underlying construct is invariant with regards to different population subgroups (or EU member states) (Chen, 2008; Greiff & Scherer, 2018; Meredith, 1993). Single-item measures are also typically associated with higher measurement error with a concomitant less precise assessment of the underlying construct (Allen et al., 2022).

On the other hand, composite indexes typically provide more robust psychometric insights into the multi-dimensional nature of loneliness (e.g., for general loneliness: Russell et al., 1978; for emotional and social loneliness: DiTommaso & Spinner, 1993), across different age groups (e.g., children, Asher et al., 1984, Marcoen et al., 1987; adolescents, Marcoen et al., 1987; adults, DiTommaso & Spinner, 1993), and different contexts (e.g., school, Twenge et al., 2021; work, Wright et al., 2006). The most-used questionnaires of loneliness include the various versions of the UCLA Loneliness Scale (Russell, 1996; Russell et al., 1978, 1980) and the De Jong Gierveld Loneliness Scale (DJGLS; De Jong Gierveld & Kamphuis, 1985). While these questionnaires are specifically designed to overcome the limitations of single-item measures, a major drawback to using them in population surveys is their length. Ultimately, the distinction between single-item and multiple-item measures comes down to a tradeoff balancing the required accuracy and precision of inferences drawn from these measures, pragmatic issues and intended use, and the associated diminishing returns of adding items.

Researchers have therefore reduced lengthier scales to a three-item UCLA Loneliness Scale (T-ILS; Hughes et al., 2004), designed to assess general loneliness, and a six-item DJGLS (DJGLS-6; De Jong Gierveld & Van Tilburg, 2006), designed to assess either general loneliness or social and emotional loneliness. Recent item-content analysis on both scales suggests that the T-ILS assesses social loneliness (with the three items) and that the DJGLS-6 assesses both social loneliness (with two items) and emotional loneliness (with three items), with one item identified as not measuring loneliness (Maes et al., 2022).

**Gaps in Our Psychometric Understanding of the DJGLS-6, the T-ILS, and single-item measures in the EU**

Overall, some psychometric evidence for the factor structure and the comparability of the DJGLS-6 and the T-ILS, as well as evidence for the reliability and the construct validity of the DJGLS-6, T-ILS, and direct measures of loneliness in the EU exist, but considerable gaps remains if one were to use these measures for population monitoring.

Recent reviews of the available evidence of internal consistency (coherence of response patterns among items) of the DJGLS-6 (Alsubheen et al., 2023) and the T-ILS (Alsubheen et al., 2021) show that their respective factor structure has been studied unevenly across the EU. The DJGLS-6 demonstrated a two-factor model in Bulgaria, France, Germany, the Netherlands, and Spain (Caballer et al., 2022; De Jong Gierveld & Van Tilburg, 2006, 2010) but no data seem available for other countries. Conversely, evidence of structural validity for the T-ILS appears to be lacking in the EU, with apparently no formal assessment of its factor structure to date. In addition, the DJGLS-6 demonstrated evidence of sufficient internal consistency in Bulgaria, France, Germany, and the Netherlands (De Jong Gierveld & Van Tilburg, 2006, 2010), but insufficient internal consistency in Spain (Caballer et al., 2022), whereas evidence of sufficient internal consistency has been reported for the T-ILS in Denmark, Finland, Germany, Hungary, Norway, and Spain (Anderssen et al., 2020; Caballer et al., 2022; Jakobsen et al., 2020; Lukács et al., 2019; Mund et al., 2023; Oksanen et al., 2023; Witthöft et al., 2022). However, internal consistency is typically examined through Cronbach’s α, which often yields biased estimates of internal consistency due to the assumption that each item in a scale has the same true score variance, which rarely holds (Flora, 2020; McNeish, 2018; Sijtsma, 2009).

Furthermore, while measurement invariance (equivalent psychometric meaning of the measured construct across subgroups) is a prerequisite to meaningfully compare loneliness scores between groups (Chen, 2008; Greiff & Scherer, 2018; Meredith, 1993), its evidence for the DJGLS-6 and the T-ILS in the EU is still lacking (Alsubheen et al., 2021, 2023). Country differences in loneliness across Europe (e.g., De Jong Gierveld & Tesch-Römer, 2012; Hansen & Slagsvold, 2016; Surkalim et al., 2022; Yang & Victor, 2011) may therefore rest on statistical artifacts if scalar invariance of the loneliness measure employed cannot be established between different regions. It is therefore unclear to what extent the DJGLS-6 and T-ILS can be meaningfully compared across EU member states, potentially rendering prevalence comparisons between countries biased. Of course, for single-item measures, no possibilities to meaningfully model the underlying latent factor and to test measurement invariance or internal consistency exist.

Similar gaps exist for these measures’ construct validity (operationalized using the nomological network – a theoretical structure connecting observations and constructs). Scores to these measures have been associated with indicators of social connectedness, emotions, and health, but evidence has been gathered non-exhaustively across the EU. For instance, higher scores on the DJGLS-6 (indicating greater feelings of loneliness) were found among participants who lived alone (Austrian and Greek samples; Heidinger & Richter, 2020; Parlapani et al., 2020), and those that were non-married (Croatian and German samples; Kristensen et al., 2019; Piccitto et al., 2022). Higher scores were also associated with poorer subjective health (Dutch and Spanish samples; De Jong Gierveld & Van Tilburg, 2006; Pino et al., 2014), higher depressive symptoms (French, German, Irish, and Italian sample; Cena et al., 2023; Kristensen et al., 2019; Schnittger et al., 2012; Van den Broek & Grundy, 2018), and more frequent suicidal thoughts (Estonian sample; Stickley et al., 2018).

Similarly, while the T-ILS has demonstrated evidence of construct validity in Austria, Belgium, Czech Republic, Luxembourg, and Spain (Ayuso-Mateos et al., 2023; Loran et al., 2021; Mayerl et al., 2021; Meckovsky et al., 2023; Ribeiro et al., 2021), evidence from other EU member states appears to be lacking. Higher loneliness scores to the T-ILS (indicating greater feelings of loneliness) were observed more frequently among non-married individuals (Czech and Luxembourger samples; Meckovsky et al., 2023; Ribeiro et al., 2021), as well as in individuals with higher depressive symptoms (Austrian and Spanish samples; Ayuso-Mateos et al., 2023; Mayerl et al., 2021), and higher psychological distress (Belgian sample; Loran et al., 2021).

Finally, evidence of good test-retest reliability has recently been reported for three single-item measures of loneliness (i.e., “I feel lonely”, “I feel alone”, “How often do you feel lonely”) in a German sample (Mund et al., 2023). The authors also reported the single-item measures to be well-integrated into a nomological network of variables. For instance, single-item measures yielded higher loneliness scores among participants with higher depressive symptoms, smaller support network, or less satisfaction with friends and social contacts. However, these results may not generalize to other single-item measures or across the EU. In sum, a broader evaluation of a variety of measurement properties of the DJGLS-6, T-ILS, and the single-item measure of loneliness included in the present study is needed to determine their suitability for EU population surveys.

**Research Overview**

The goal of the present study was to provide an EU-wide evaluation of the measurement properties of three loneliness measures potentially suitable for population surveys: the DJGLS-6, the T-ILS, and a single-item measure of loneliness. Our work contributes to the existing literature by providing an assessment of the factor structure, reliability, measurement invariance, and nomological network of the DJGLS-6 and T-ILS and the nomological network of a single-item measure of loneliness for all the 27 EU member states. To do so, we relied on data from the *EU Loneliness Survey*, an EU-wide survey conducted by the JRC in collaboration with the Directorate-General for Employment, Social Affairs & Inclusion and totaling 25,646 respondents covering the 27 EU member states.

Based on previous research, we expected the DJGLS-6 to provide an adequate fit for a two-factor model assessing emotional and social loneliness with sufficient internal consistency, and the T-ILS to provide a sufficient fit for a one-factor model assessing social loneliness with sufficient internal consistency (ω ≥ .60). We also expected the DJGLS-6, T-ILS, and direct measure of loneliness to be well integrated into their nomological network, with positive correlations between loneliness scores and indicators of negative emotions, and negative correlations between loneliness scores and indicators of social connectedness, positive emotion, and health. However, our confidence in deriving these predictions was not very strong given that the psychometric properties of the DJGLS-6, T-ILS, and single-item measures have been examined unevenly across the EU. We did not have any predictions for the outcomes of our measurement invariance analyses, given the dearth of research on the topic across the EU. This involved systematically testing at what level of invariance the data generated by the measures support. The goal was to examine whether the psychometric meaning of the measured constructs was equivalent across different cultural contexts, gender, and age.

**Methods**

**Participants**

The respondents of the *EU Loneliness survey* (*N* = 25,646) were recruited from established online consumer panels, with approximately 1,000 completed responses per country except for Cyprus, Luxembourg and Malta (*N* *=* 503, *N* *=* 370 and *N* *=* 529, respectively). The targeted population were adults 16 years or older, who were residents in the country. We used quotas based on the population of each Member State to reflect the target population in terms of age, gender, educational attainment, and Nomenclature of Territorial Units for Statistics (NUTS) region of residence. These simple, non-interlocking quotas were mapped to population shares calculated from Eurostat's official population statistics by male/female gender, six age groups (16-25, 26-35, 36-45, 46-55, 56-65, and 65+), three education groups (International Standard Classification of Education ISCED level 0-2; levels 3 and 4 and levels 5-8); and 2-16 geographical regions depending on the country. Moreover, *ex-post* sampling weights were calculated to account for possible further underrepresentation of the abovementioned socio-demographic groups. We present the sample sizes and descriptives on age, gender, and loneliness scores by country in Table 1.[[2]](#footnote-3)

**Data collection**

Data collection occurred between November and December 2022 and was implemented by a Consortium consisting of LE Europe, Ipsos and VVA Market Research. The recruitment and sampling strategy was based on the use of panel providers with established online consumer panels in all EU 27 Member States. For this specific survey, the Consortium collaborated with the Cint online platform, a single network of panels that covered all EU 27 Member States. Following the JRC’s collection requirements, selected panelists should not have completed any survey in the last 14 days.

The survey was originally drafted in English. Once the English version was finalized, professional translators forward-translated the entire survey into the national language of each member state (with the exception of Ireland and Malta, where only an English version of the survey was used). Thirty-one out of the 82 survey questions of the main questionnaire were back-translated. Back translation was reserved for more complex questions. For the remainder of the questions either existing translations (4 questions) or forward-translation were used. Instructions to translators are provided in the survey on our OSF page: <https://osf.io/unfrc/>.

Eligible participants received invitations to fill the online survey, for an average completion time of 28 minutes. The JRC Research Ethics Board (REB) reviewed the project for the data collection. As the survey included sensitive and ‘special category’ data as defined under the General Data Protection Regulation (GDPR), such as questions on health, participants were asked to give informed consent to participate in the survey by answering positively to the question "Do you agree to answer the survey?". If participants did not agree, they were informed that they could not continue the survey and then asked once again for their agreement. Participants then answered questions. The T-ILS and DJGLS-6 were counterbalanced in order, such that half of the respondents were randomly assigned to a version of the questionnaire where the T-ILS was shown first and the DJGLS-6 second, with a battery of unrelated questions in between, and for the other half of the sample the order of the scales was reversed. The first section of the survey included screening and profiling questions that gathered demographic information to implement the quotas. Respondents were then screened out if they were not eligible based on age (i.e. less than 16 years old) or if their quota had already been filled (i.e., the maximum number of responses for the relevant socio-demographic group had already been reached). Following the screening questions, participants answered the survey.

**Measures**

Loneliness was assessed using the DJGLS-6, T-ILS, and a single-item measure. The DJGLS-6 consisted of six items (e.g., “I miss having people around”) answered with *No* (0),

*More or less* (1), or *Yes* (2), and was used to measure social and emotional loneliness. The T-ILS consisted of three items (e.g., “How often do you feel isolated from others”) answered with *Hardly ever or never* (1), *Some of the time* (2), or *Often* (3), and was used to measure general loneliness. Both the DGLS-6 and T-ILS were averaged into a single score. The single-item measure came from the EUSILC survey (European Commission, 2018), and asked the respondent to report on the frequency of feeling lonely over the preceding 4 weeks (i.e., “How much of the time, during the past 4 weeks, have you been feeling lonely”) on a 5-point scale, ranging from *None of the time* to (1) to *All of the time* (5). For all measures, higher scores indicated higher loneliness. All the loneliness measures included in this survey are also provided in Table 2.

Several modules covering a variety of topics were administered along with the loneliness measures. These modules included –but were not limited to– social media consumption behaviors (17 items; e.g., “I use social media to get in contact with new people”), civic attitudes (3 items; e.g., “I’m willing to give to good causes without expecting anything in return”), or childhood experiences (5 items; e.g., “When growing up, have you always lived with both of your parents?”), social support (4 items, e.g., “How often is each of the following types of support available to you, if you need it: Someone to help you if you were confined to bed”).

We selected three categories of measures to be part of the nomological network analyses: 1) social activities and attitudes, which consisted of a) a composite measure of perceived social support (4 items; e.g., “how often is available someone to share your most private worries and fears with”, ω= .86) and b) single-item measures of the participants’ closeness in relationship with friends (“How many of your friends would you say you have a close relationship with?”) and family (“How many of your family members would you say you have a close relationship with?”), occurrences of in-person meetings with friends (“On average, how often do you do each of the following with any of your friends? Meet up face-to-face (include both arranged and chance meetings)”) and family (“On average, how often do you do each of the following with any members of your family (e.g., brothers, sisters, parents, children, in-laws or grandchildren)? Meet up face-to-face (include both arranged and chance meetings)”), frequency of virtual meetings with friends (“On average, how often do you do each of the following with any of your friends? Talk/chat via phone, internet or social media”) and family (“On average, how often do you do each of the following with any members of your family (e.g., brothers, sisters, parents, children, in-laws or grandchildren)? Talk/chat via phone, internet or social media”), occurrences of contacts with neighbors (“How often do you have any contact, even something as simple as saying "hello", with any of your neighbours?”), and frequency of participation in social activities (“Over the last 12 months, how frequently did you do each of the following activities? Participated in social activities of a club, society and/or association”), 2) one-item indicators of emotional states (depression [“Over the past week, how frequently have you felt the following way? Depressed”] and happiness [“Over the past week, how frequently have you felt the following way? Happy”]), and 3) an indicator of health (“In general, would you say your (physical and mental) health is”. The full survey and all answer options are available at our OSF page: <https://osf.io/3dxsv/>.

**General Analytic Plan**

We followed a cross-validation procedure to evaluate the measurement properties of the DJGLS-6, T-ILS, and single-item measure of loneliness. Elizabeth Casabianca, an author not involved at the level of data contingent choices, chose a fixed random seed number and used a dedicated R script to automatically partition the dataset into two folds—exploratory and confirmatory—of equal sample sizes[[3]](#footnote-4). Stratification was performed based on the *country* variable to maintain a consistent representation of countries between folds. We first conducted the analyses of the measurement properties of the loneliness instruments on the exploratory fold. Once we had analyzed the exploratory fold, we then wrote our conclusions and – based on the findings – pre-registered resulting hypotheses prior to testing them in our confirmatory fold.

For the DJGLS-6, we (a) determined the optimal factor structure through exploratory factor analyses and subsequently validated it by confirmatory factor analysis, along which we evaluated the fit of the factor structures usually employed in the literature using confirmatory factor analysis, (b) assessed their internal consistency using McDonald’s ω, (c) assessed their measurement invariance properties (across countries, and within clusters of countries that were invariant, across gender and age) through a combination of multigroup confirmatory factor analyses and mixture multigroup factor analyses. For the T-ILS, we carried out the same analysis except for where the three-item structure does not allow for a formal test of the factor model. There, we assessed the internal structure by the adequacy of factor loadings only. Finally, we evaluated the construct validity of the DGLS-6, T-ILS, and single-item measure of loneliness through analyses of their nomological network. We conducted analyses using the R programming language (version 4.3.1.; R Core Team, 2022). All our scripts are available at our OSF page: <https://osf.io/7u4e8/>.

***Factor Analyses and Internal Consistency***

The DJGLS-6 is typically thought to consist of two factors (assessing emotional and social loneliness; De Jong Gierveld & Van Tilburg, 2006), while the T-ILS is thought to consist of one factor (assessing general loneliness; Hughes et al., 2004). However, given that factor structure is relatively unexamined in EU-wide samples, in our first fold, we conducted both exploratory (exploring the optimal factor structure for both scales) and confirmatory (testing the two predicted factors for the DJGLS-6 and one factor for the T-ILS) factor analyses to identify its optimal structure across countries, balancing theoretical parsimony with model fit.

To retain the most optimal factor structure following exploratory factor analyses, we used Empirical Kaiser Criterion (Braeken & Van Assen, 2017). As a robustness check, we also report the results of parallel analysis (Horn, 1965) in the supplementary materials. Parallel analysis and Empirical Kaiser Criterion both retain a factor structure when its eigenvalue is greater than the mean eigenvalue from its random counterpart. The Empirical Kaiser Criterion tends to outperform parallel analysis when used on short scales with correlated dimensions (Braeken & Van Assen, 2017). In case these methods yielded inconsistent results, we favored the factor structure identified by the Empirical Kaiser Criterion but for the sake of transparency, we also mentioned the inconsistency of results when an alternatively justifiable method is used. We subsequently conducted confirmatory factor analyses to assess the fit of the structure we retained.

Following common guidelines, we evaluated the fit as acceptable with Comparative Fit Index (CFI) values ≥ .90 and Root Mean Squared Error of Approximation (RMSEA) values ≤ .08, and as very good with CFI values ≥ .95 and RMSEA values ≤ .06 (De Roover et al., 2022; Hu & Bentler, 1999). Given the large size of the sample included in the study, we expected the χ² test of model fit to consistently return significant *p*-values. Consequently, we did not use *p*-values nor RMSEA confidence intervals to make inferences when evaluating the fit of the factor structures (but still reported them for the sake of transparency and completeness). Instead, we considered the model fit to be sufficient with CFI values ≥ .90 and RMSEA values ≤ .08 (see also De Roover et al., 2022; Hu & Bentler, 1999). In parallel, we conducted confirmatory factor analyses to assess the fit of the structures typically used in the literature for both measures (i.e., two factors assessing emotional and social loneliness for the DJGLS-6; one factor assessing general loneliness for the T-ILS), using the same guidelines to evaluate model fit (i.e., acceptable with Comparative Fit Index (CFI) values ≥ .90 and Root Mean Squared Error of Approximation (RMSEA) values ≤ .08; good with CFI values ≥ .95 and RMSEA values ≤ .06). If the factor structure typically used in the literature did not match the most optimal structure identified through exploratory factor analysis, we decided on a structure for the subsequent analyses. Again, our decision aimed to balance theoretical parsimony with model fit.

We conducted the factor analyses using the Weighted Least Squares Mean and Variance adjusted (WLSMV) estimation method whenever possible. This choice stemmed from the unsuitability of treating the DJGLS-6 and T-ILS as continuous measures due to their response formats (i.e., 3-point Likert type answers for both measures). Previous research has shown that treating this type of measures as continuous would challenge the assumption of multivariate normality that undermines the Maximum Likelihood (ML) estimation method commonly employed in factor analyses, making this estimation method less appropriate for measures answered with less than five response categories (Li, 2015; Rhemtulla et al., 2012; for contrasting views, see Robitzsch, 2020). All aggregate (across countries) latent models employed sampling weights to balance out unequal sampling probabilities caused by the fact that sample sizes across countries were similar (while country population sizes vary widely). For all latent variable models, we handled the missing data using listwise deletion, as only 1.9% of the data for loneliness measures were missing. Here, we preferred the ability to directly model the ordinal character of the data using WLSMV over imputing the little amount of missing data by Full Information Maximum Likelihood.

Finally, we assessed the internal consistency of the DJGLS-6 and T-ILS for each country separately using McDonald’s omega (ω). While the Cronbach's alpha (α) is the most popular metric for assessing internal consistency, its use is conditioned by a set of assumptions that are rarely met, leading to the reporting of biased estimates of internal consistency in most cases (Flora, 2020; McNeish, 2018; Sijtsma, 2009).

To select the right metric for internal consistency of the DJGLS-6 and T-ILS, we followed guidelines reported by Flora (2020) and reported the ω for unidimensional categorical items. There are no clear guidelines as to which minimum ω value would indicate sufficient internal consistency, with some authors suggesting a minimum value ranging between .50 and .70 (Tavakol & Dennick, 2011; Watkins, 2017). As internal consistency is positively correlated to the number of items of a measure (Cortina, 1993), we took a medium ω value ≥ .60 as indicator of sufficient internal consistency given the short length of the DJGLS-6 and T-ILS.

***Measurement Invariance***

We conducted measurement invariance tests to assess the comparability of scores from the DJGLS-6 and T-ILS across countries in the EU (as well as across gender and age for clusters of countries that were invariant), using a combination of multigroup confirmatory factor analysis (Meredith & Teresi, 2006) and mixture multigroup factor analysis (De Roover, 2021; De Roover et al., 2017, 2022). In practice, measurement invariance tests are often conducted through multigroup confirmatory factor analysis and allow for establishing measurement invariance at three different levels, in an incremental manner. First, configural invariance is established if the factor structure of the measurement model is equivalent across groups. In case configural invariance holds, metric (weak) invariance is then established if factor loadings are equivalent across groups, after which scalar (strong) invariance is established if both factor loadings and item intercepts are equivalent across groups. Following the rejection of one level of measurement invariance, researchers usually resort to pairwise comparisons of specific groups to establish that level of measurement invariance in a smaller number of groups.

One important drawback to this strategy is the number of comparisons one would have to do in case the number of groups is large: With 27 groups (i.e., one for each EU member state), the number of pairwise comparisons would amount to 351, which increases the risk of false positives and makes it hard to disentangle invariant parameters from non-invariant parameters, and for which groups they apply (De Roover et al., 2022). Mixture multigroup factor analysis proposes a parsimonious solution to that problem, as it allows to unravel clusters of groups in which the measurement model is invariant across groups on both factor loadings and item intercepts (i.e., clusters of groups that are invariant at the scalar level). Only under scalar invariance is it then justified to compare prevalence rates across countries and interpret the observed differences between countries’ scale scores as the difference in the level of the underlying construct. However, mixture multigroup factor analysis is still an imperfect solution to our specific case, as it models factor analyses using the Maximum Likelihood (ML) method, which – as explained above – is less appropriate on 3-point Likert type measures like the DJGLS-6 and T-ILS.

Our procedure for testing measurement invariance was thus as follows: We first tried to establish measurement invariance across the 27 EU member states using multigroup confirmatory factor analysis. Configural invariance was established following the same indicators as for our confirmatory factor analyses (CFI ≥ .90 and RMSEA values ≤ .08), metric invariance was established in case the model that imposed equivalent factor loadings had significant ΔCFI value ≥ -.02 or ΔRMSEA value ≤ .03 compared to the configural model, and scalar invariance was established in case the model that imposed equivalent factor loadings and item intercepts had ΔCFI value ≥ -.02 or ΔRMSEA value ≤ .03 compared to the metric model. Those cut-offs values appear to be appropriate for detecting measurement invariance across many groups (Rutkowski & Svetina, 2014).

In case measurement invariance failed at any level, instead of doing pairwise comparisons to pinpoint invariant countries, we resorted to mixture multigroup factor analysis to unravel clusters of countries invariant at the scalar level. Loneliness scores would then be comparable within the given cluster of countries. Specifically, we used the *MixtureMG\_FA* function from the *mixmgfa* R package (De Roover, 2021; De Roover et al., 2022) to provide cluster solutions of countries with equivalent factor loadings and item intercepts. We selected the best clustering solution using a combination of (a) the Convex Hull procedure (CHull; Ceulemans & Kiers, 2006; Ceulemans & Van Mechelen, 2005), which is a generalization of the scree-test (Cattell, 1966) that provides the optimal clustering solution via a maximized scree ratio and visual detection of an elbow in the CHull plot; and (b) the Bayesian Information Criterion (BIC; Schwarz, 1978) with the number of groups G as sample size (BIC\_G) that provides the optimal clustering solution via a minimized BIC\_G value.

In case the two methods yielded different optimal clustering solutions, we favored the clustering solution returned by the CHull method, which does not make distributional assumptions on the data (De Roover et al., 2022). Following this, as mixture multigroup factor analysis does not support the estimation method that best fits categorical data (De Roover et al., 2022), we subsequently assessed measurement invariance on the unraveled clusters using multigroup confirmatory factor analysis again and concluded on the invariance of the measure following these analyses.

For each cluster of countries, where the measures exhibited strong invariance of measurement properties, we also tested invariance across levels of gender (female/male) and age (in 6 groups: 16-25, 26-35, 36-45, 46-55, 56-65, 65+), using the same approach and criteria.

***Construct Validity: Nomological Network***

We evaluated the construct validity of the DJGLS-6, T-ILS, and single-item measure of loneliness through analyses of their nomological network, by examining latent correlations between the loneliness measures with composite measures and items concurrently administered in the EU Loneliness Survey, for each country separately. For multiple-item measures, we have fitted a CFA model using WLSMV estimator, explicitly modeling the items as ordered, and extracted the measurement error-free for the unitary latent factor. For single-item measures, we conservatively assumed ~50% reliability (to make the measurement model identified), modeling a latent variable having a single ordered indicator by fixing the factor loading to .70. Then, we computed zero-order Pearson’s correlation coefficients to quantify the relationship between the measurement error-free factor scores of the three loneliness measures with factor scores for indicators of social activities and attitudes, indicators of emotions, and an indicator of health.

We considered the loneliness measures to show sufficient construct validity in case at least two-thirds of the latent correlations obtained were in the expected direction, significant at the .05 level adjusted with Bonferroni correction applied at the country level (with 12 correlation tests per country, this corresponds to an α threshold adjusted to .004), and a | *r |* ≥ .10. We expected positive latent correlations between the loneliness scores and the indicator of negative emotion, and negative correlations between the loneliness scores and the indicators of social activities and attitudes, positive emotion, and health. In addition, we computed latent correlation coefficients to quantify the relationship between the three loneliness measures (i.e., the DJGLS-6, T-ILS, and single-item measure of loneliness).

For the estimation of zero-order correlations of factor scores, we handled the 1.9% of missing data using pairwise deletion.

**Results**

**Results from the exploratory fold**

In summary, both the DJGLS-6 and T-ILS provided evidence of adequate measurement properties on factor structure, internal consistency, measurement invariance, and construct validity. More specifically, the DJGLS-6 provided a good fit for a two-factor structure for 14 countries, sufficient internal consistency (for both subscales) for 24 countries, provided evidence of measurement invariance across two different clusters of countries, and provided evidence of sufficient construct validity for 25 countries. The T-ILS showed sufficient internal consistency for all 27 countries, provided evidence of measurement invariance across the 27 EU member states, and provided evidence of sufficient construct validity for 22 countries. The one–item measure of loneliness provided evidence of sufficient construct validity for 19 countries.

***Factor Analyses and Internal Consistency***

Following factor analyses in our exploratory fold, we decided to retain a two-factor structure for the DJGLS-6, and a one factor structure for the T-ILS. The DJLGS-6 provided a very good fit to a two-factor structure for 8 countries, good fit for 6 countries and poor fit for 13 countries, with sufficient internal consistency for 24 countries. For the T-ILS, the unitary factor explained the majority of variance (λ > .71) for all the three items in 25 countries and the scale score showed sufficient internal consistency for all countries. Table 3 presents the model fit and internal consistency values obtained across the 27 EU member states and for each member state separately, for each measure.

**DJGLS-6.** Results of the parallel analysis and Empirical Kaiser Criterion extraction techniques suggested that a two-factor structure was the most appropriate for the DJGLS-6 across the 27 EU member states. We found this two-factor model to provide a good fit to the data (χ² = 299, *df* = 8, *p* < .001, CFI *=* .989, RMSEA = .055, CI 90% [.050, .060]). The scale scores had a sufficient mean internal consistency (ωsocial = .82, ranging from .78 to .86; ωemotional = .73, ranging from .56 to .86. The scale showed – in accordance with our a priori set standard of ω = .60 – insufficient internal consistency in Finland, France, and Romania (emotional subscale, in all three cases).

In parallel, we tested the model fit of the two-factor structure usually employed in the literature across the 27 EU member states, using confirmatory factor analysis. We also tested a unitary factor model and found the model to provide a poor fit to the data (χ² = 3023, *df* = 9, *p* < .001, CFI *=* .887, RMSEA = .166, CI 90% [.161, .171]) with sufficient mean internal consistency (ω = .90). The unitary factor model fitted the data significantly worse, χ²diff = 1103, *p* < .001. We therefore chose to retain the two-factor structure. This structure thus acted as a representation of the overarching loneliness construct subjected to further measurement invariance assessment and nomological network analyses.

For the structure we retained, we report the model fit indices and internal consistency obtained across the 27 EU member states and for each country separately in Table 3.

**T-ILS.** As the T-ILS is a three-item scale, the only possible hierarchical structure is a one-factor structure, corresponding to the factor structure employed in the literature. As this model has zero degrees of freedom and is thus just-identified, it is not possible to subject it to a formal model test. The fitted unitary model explained the variance in the three items well in 25 countries, as all item loadings were above .71 (denoting >50% construct-relevant variance), ranging from .79 to .92. The scale showed sufficient internal consistency, with a mean ω= .83, with estimates ranging from .77 to .87, thus showing sufficient internal consistency for all countries. We report the factor loadings and internal consistency of the scale obtained across the 27 EU member states and for each country separately in Table 3.

***Measurement Invariance***

We conducted multigroup confirmatory factor analyses to establish configural, metric, and scalar invariance of the DJGLS-6 and T-ILS across the 27 EU member states, in an incremental manner. As we failed to establish measurement invariance for the DJGLS-6 at the scalar level, we resorted to mixture multigroup factor analyses to unravel clusters of countries invariant at the scalar level, and subsequently performed multigroup confirmatory factor analyses on the unraveled clusters as sensitivity tests.

**DJGLS-6**. To establish configural invariance of the DJGLS-6, we first assessed if the two-factor structure of the measure provided an acceptable fit for the 27 EU member states using multigroup confirmatory factor analysis. The two-factor structure provided a poor fit across the 27 EU member states (χ² = 910, *df = 216, p* < .001, CFI *=* .992, RMSEA = .085, CI 90% [.079, .090]), which suggests that configural invariance does not hold across the countries and which suggests that the same measurement model does not hold for all groups.

As configural invariance could not be established using multigroup confirmatory factor analysis, we resorted to mixture multigroup factor analysis to unravel clusters of countries with equivalent factor loadings and item intercepts (i.e., clusters of countries invariant at the scalar level). We computed a mixture multigroup factor analysis on the two-factor structure of the DJGLS-6 across the 27 EU member states by using the *MixtureMG\_FA* function of the *mixmgfa* R package (De Roover, 2021; De Roover et al., 2022). We set the function to provide cluster solutions from 1 to 6, with 5000 iterations and 50 runs, and constrained the measurement model to have equivalent factor loadings and item intercepts per cluster. Both the Convex Hull procedure and BIC\_G criterion suggested a 3-clusters solution. After further inspection of the Convex Hull plot, we decided to retain a 3-clusters solution as a clear elbow could be detected on the plot around the 3-clusters solution. The clusters were the following: Cluster A (Estonia, Finland, France, Romania), Cluster B (Belgium, Bulgaria, Croatia, Cyprus, Czechia, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, Portugal, Slovakia, Slovenia, Spain), and Cluster C (Austria, Denmark, Latvia, Lithuania, Netherlands, Poland, Sweden). That the countries are invariant at the scalar level within these clusters means that the mean scores on the DJGLS-6 can safely be compared within, but not across, these three clusters.

As mixture multigroup factor analysis currently does not handle categorical data in the most appropriate way, we further conducted multigroup confirmatory factor analyses on the unraveled clusters. We display the results of these analyses in Table 4. The findings were consistent with the conclusions drawn from the mixture multigroup factor analysis for clusters B and C, where scalar invariance was successfully established. However, for cluster A, we failed to establish configural invariance.

Within cluster C, the DJGLS-6 also showed strong (scalar) measurement invariance across levels of gender (women/men) and age (16-25, 26-35, 36-45, 46-55, 56-65, 65+), meaning that the mean scores for men and women and across age groups within cluster C can be compared. Within cluster B, however, we failed to establish configural invariance across levels of gender and age. The detailed results are shown in the supplementary materials.

**T-ILS.**Given that an unrestricted unitary factor model with just three indicators is just-identified, it is not possible to assess configural invariance. Therefore, to assess measurement invariance, we directly imposed equal factor loadings across countries and thus tested metric invariance as the first step. The metric model showed a good fit to the data (*χ²* = 93, *df* = 52, *p* < .001, *CFI =* .999, *RMSEA* = .041, CI 90% [.027, .055]), suggesting that metric invariance holds across the countries and that the factor loadings and factor structure is identical across groups.

To establish scalar invariance of the T-ILS, we then compared the performance of a model that imposed equal factor loadings and item intercepts across countries (i.e., a scalar model) to the performance of the metric model, using multigroup confirmatory factor analysis. The scalar model performed significantly worse than the metric model, but still well in absolute terms (*χ²* = 236, *df*, = 104, *p* < .001, *CFI =* .998, *RMSEA* = .053, CI 90% [.044, .062]). Differences between the models fit were smaller than the cut-off values we set for measurement invariance (ΔCFI *=* .001, ΔRMSEA= .012), which suggests that scalar invariance holds across the countries and that the mean scores for the T-ILS can thus be compared across groups.

The T-ILS further exhibited scalar invariance across levels of genders and age. Detailed results can be found in the supplementary materials.

***Construct Validity***

We assessed the construct validity of the DJGLS-6, T-ILS, and the single-item measure of loneliness by establishing their nomological network for each country separately. In addition, we found the three measures to be significantly correlated (and in the expected direction) to the constructs in the nomological network. The two scales of the DJGLS-6 (emotional and social loneliness) showed sufficient construct validity across 25/27 (92.59%) countries, the T-ILS scale across 22/27 (81.48%) countries, and the single-item measure of loneliness for 19/27 (70.37%) countries. We provide a heatmap (Figure 1) that summarizes all the different latent correlations obtained for each country, for the DJGLS-6, T-ILS, and single-item measure of loneliness, respectively. The corresponding tables are available in supplementary materials.

To gain a more detailed insight into the predictive validity of the three loneliness measures, we have also broken down the nomological network into three more narrow domains, namely (1) social activities and attitudes (social support, closeness in relationship with friends and family, in-person and remote meetings with friends and family, contacts with neighbors, and participation in social activities), (2) emotional states (depression and happiness), and (3) health, which was reported through a one-item self-rated health question. Using the same criteria as for the full nomological network, loneliness measures show predictive validity for the three domains in the following number of EU countries: DJGLS-6, 24 countries (88.89%) for social activities and attitudes, 27 (100%) for emotional states, and 25 (92.59%) for health; T-ILS, 19 countries (70.37%) for social activities and attitudes, 27 (100%) for emotional states, and 27 (100%) for health; Single-item measure, 14 countries (51.85%) for social activities and attitudes, 27 (100%) for emotional states, and 26 (96.30%) for health.

Lastly, apart from the separate nomological networks for the three loneliness measures, we have also examined the convergent validity by estimating their intercorrelations (Pearson’s correlations of factor scores). The results show that the emotional subscale of the DJGLS-6, T-ILS, and the single-item measure of loneliness all correlate at between .68 and .69. The social subscale of the DJGLS-6, however, exhibited markedly smaller correlations with the other scales ranging from .31 (with the social subscale) to .43 (with T-ILS). Overall and per-country latent correlation matrices for all study variables can be found in supplementary materials.

**Summary of the Exploratory Fold and Hypotheses for the Confirmatory Fold**

In our exploratory fold, we found that overall, the factor structure for the T-ILS and for the DJGLS-6 holds and that the reliability is sufficient across countries (with the exception of Finland, France, and Romania; DJGLS-6 emotional subscale). The T-ILS demonstrated scalar invariance across all countries, which means that its scores are comparable across the EU. It also exhibited scalar invariance for gender and age. For the DJGLS-6, on the other hand, both the model and scores are not fully comparable across countries, but only within two distinct clusters of countries. A third cluster of countries was identified for the DJGLS-6, but configural invariance could not be established in it.

When examining the scales’ content validity through a surface examination nomological network, the DJGLS-6 provided sufficient construct validity in 25/27 countries, whereas the T-ILS showed sufficient construct validity for 22/27 countries. For the single-item measure of loneliness, we are unable to provide information about its comparability across countries, whether it maps onto the construct through its underlying factor structure, or its internal coherence. Again, on the surface, the single-item loneliness measure shows sufficient construct validity for 19/27 countries.

Building on the findings obtained from the analyses conducted on the exploratory fold, we pre-registered a new set of hypotheses, aiming to replicate and cross-validate the exploratory findings in the confirmatory fold. More specifically, we pre-registered (1) the factor structure (to assess with confirmatory factor analysis directly) and internal consistency of the DJGLS-6 two-factor structure, and the T-ILS one-factor structure, (2) the measurement invariance properties (to assess with multigroup confirmatory factor analyses directly) obtained for the DJGLS-6, and for the T-ILS, and (3) the correlations obtained through the nomological network analyses, for the DJGLS-6, T-ILS , and for the single-item measure of loneliness.

We applied the following rules for judging the replication success. (1) For model fit evaluation, we applied the same criteria as in exploratory fold. When the analysis in the confirmatory fold led to the same conclusion, we deemed that as a successful replication, either of a positive (+/+) or negative result (-/-). In case the conclusion regarding the adequacy of model fit diverged, we considered the data to be inconclusive. (2) For reliability, if the internal consistency estimates for the exploratory and confirmatory fold were on the same side of the .6 threshold, we considered it a successful replication. (3) For invariance testing, we considered the measurement properties to be invariant if at least the same level of invariance at least across the given cluster of countries was found in the confirmatory fold. (4) For nomological network, we applied Fisher's *z*-transformation to the correlation coefficients from exploratory and confirmatory fold and calculated the *z*-score for their difference. We then used a BIC approximation (implicitly assuming a unit information prior) to compute Bayes factors (Wagenmakers, 2007) to assess to what degree do the data support the H0 of no difference between the correlations. We deemed the given correlation effect successfully replicated either if both correlations were significant, above |r| ≥ .10, and in the same direction, or in case the BF01 (in favor of the null) was larger than 3 (taken as an indication of equivalence of the correlation coefficients).

***Factor analyses and internal consistency***

We replicated both the factor structure configuration and internal consistency of the DJGLS-6 and T-ILS obtained on the exploratory fold for XX countries out of XX for the DJGLS-6, and XX countries out of XX for the T-ILS.

**DJGLS-6.** [In line with the results of the exploratory analyses/Contrary to the results of the exploratory analyses], the DJLGS-6 provided [a poor/an acceptable/a very good] fit to a [one/two] factor structure, [with a sufficient/but, with an insufficient] level of overall internal consistency equal to ω = XX. The country-specific factor structure found in the exploratory fold was cross-validated in XX countries out of XX, with sufficient (ω > .60) internal consistency for XX countries out of XX. [Here, we also provide the detailed results of the same analyses as in the exploratory fold].

**T-ILS.** [Consistent with the results found in the exploratory phase/Contrary to the results found in the exploratory phase], the unitary-factor model adequately explained the variance (item loadings > .71) in [only one/only two/all three] items, yielding [a sufficient/an insufficient] level of overall internal consistency, ω = XX. The factor loadings suggested a good fit to the unitary-factor structure in XX countries out of XX, with sufficient internal consistency for XX countries out of XX. [Here, we also provide the detailed results of the same analyses as in the exploratory fold]

***Measurement invariance***

We [attained/partially attained/failed to attain] at least the same level of between-country measurement invariance of the DJGLS-6 and T-ILS obtained on the exploratory fold.

**DJGLS-6.** [In line with the results of the exploratory analyses/Contrary to the results of the exploratory analyses], the DJLGS-6 [provided/provided partial/did not provide] evidence of at least the same level of measurement invariance at least across the cluster of countries identified in the exploratory analyses [Detailed results for country, gender, and age invariance follow here].

**T-ILS.** [Consistent with the results found in the exploratory phase/Contrary to the results found in the exploratory phase], the T-ILS [provided/ provided partial/did not provide] evidence of equally restrictive measurement invariance at least across the cluster of countries identified in the exploratory analyses. [Detailed results for country, gender, and age invariance follow here].

***Construct Validity***

At least the same level of evidence (a minimum of 2/3 nomological network correlations being significant, above |r| ≥ .10, and in the same direction) about construct validity was found in XX countries (positive evidence in XX and negative evidence in XX countries) for DJGLS-6, in XX countries (positive in XX, negative in XX countries) for the T-ILS and in XX countries (positive in XX, negative in XX countries) for the single-item measure. [Here, we will describe in detail the results of testing the nomological networks].

**Discussion**

[Discussion will be added following the analyses]

**Author Contributions:** Author contributions will be added upon completion of the project.

**Conflict of Interest:** Two of the proposing authors are members of the Joint Research Centre of the European Commission (Béatrice d’Hombres and Elizabeth Casabianca). They may thus have an interest in a positive outcome of the analyses above. However, all analyses are managed and inferences are drawn by the other three authors, who do not have a vested interest in the outcome one way or another.

Three authors, including the lead author, are members of a start-up, Annecy Behavioral Science Lab, a for-profit research organization that provides multi-country research services on loneliness, social connection, and human flourishing (Bastien Paris, Hans IJzerman and Miguel Silan). This start-up is dedicated to applying rigor and pre-registration throughout the research process.

All authors thus commit to the highest standards of scientific rigor, transparency, and assessment of evidence regardless of the direction or implications of the results.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 1** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Sample Size and Descriptive Statistics by Country* | | | | |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | Age | | | Gender distribution (%) | | | Loneliness (DJGLS-6) | | | Loneliness (T-ILS) | | | Loneliness (direct) | | |
| Country | N | Mdn | Mean | SD | Male | Female | Other | Mdn | Mean | SD | Mdn | Mean | SD | Mdn | Mean | SD |
| Austria | 504 | 46 | 46.38 | 15.25 | 48.41 | 50.99 | 0.40 | 3 | 3.66 | 3.05 | 2 | 2.02 | 1.79 | 1 | 1.10 | 1.10 |
| Belgium | 502 | 47 | 47.53 | 16.47 | 47.21 | 52.39 | 0.20 | 4 | 4.51 | 3 | 2 | 2.01 | 2 | 1 | 1.16 | 1.17 |
| Bulgaria | 501 | 46 | 45.93 | 14.03 | 45.91 | 52.89 | 0.80 | 4 | 4.21 | 3.06 | 1 | 1.62 | 1.81 | 1 | 1.04 | 1.12 |
| Croatia | 505 | 48 | 47.16 | 14.21 | 48.12 | 51.29 | 0.40 | 4 | 4.63 | 2.85 | 2 | 2 | 1.69 | 1 | 1.11 | 1.03 |
| Cyprus | 252 | 39 | 40.96 | 13.57 | 46.03 | 53.97 | 0 | 4 | 4.15 | 3.13 | 2 | 2 | 1.81 | 1 | 1.11 | 1.15 |
| Czechia | 501 | 47 | 47.81 | 15.75 | 46.51 | 53.49 | 0 | 4 | 4.55 | 2.93 | 2 | 2.11 | 1.83 | 1 | 1.16 | 1.08 |
| Denmark | 504 | 45 | 46.86 | 17.78 | 48.81 | 50.40 | 0.40 | 3 | 3.59 | 3.24 | 1 | 1.86 | 1.88 | 1 | 1.16 | 1.15 |
| Estonia | 505 | 39 | 42.29 | 14.47 | 40.99 | 56.83 | 0.99 | 4 | 4.92 | 3.06 | 2 | 2.29 | 1.98 | 1 | 1.19 | 1.15 |
| Finland | 504 | 48 | 46.88 | 15.74 | 47.62 | 50.79 | 1.59 | 4 | 4.22 | 2.91 | 2 | 2.10 | 1.91 | 1 | 1.05 | 1.07 |
| France | 500 | 50 | 50.02 | 15.97 | 47.40 | 52.20 | 0.40 | 4 | 4.23 | 2.67 | 1 | 1.46 | 1.70 | 1 | 1.09 | 1.05 |
| Germany | 553 | 53 | 51.74 | 15.19 | 50.81 | 49.01 | 0.18 | 4 | 4.06 | 2.95 | 2 | 2.02 | 1.78 | 1 | 1.11 | 1.15 |
| Greece | 504 | 46 | 44.33 | 11.96 | 48.02 | 50.79 | 0.60 | 4 | 4.33 | 3.05 | 2 | 2.27 | 1.90 | 1 | 1.28 | 1.17 |
| Hungary | 502 | 48 | 48.95 | 15.52 | 49.40 | 50.40 | 0 | 4 | 4.41 | 2.94 | 2 | 1.91 | 1.84 | 1 | 1.01 | 1.13 |
| Ireland | 505 | 37 | 38.70 | 13.69 | 50.30 | 48.32 | 0.79 | 5 | 4.90 | 2.96 | 2 | 2.32 | 1.88 | 1 | 1.46 | 1.17 |
| Italy | 500 | 51 | 50.43 | 16.13 | 51 | 49 | 0 | 4 | 4.12 | 2.98 | 1 | 1.84 | 1.89 | 1 | 1.15 | 1.15 |
| Latvia | 505 | 44 | 44.37 | 13.82 | 45.54 | 53.27 | 0.59 | 5 | 5.01 | 2.92 | 2 | 2.04 | 1.81 | 1 | 1.12 | 1.08 |
| Lithuania | 506 | 48 | 47.40 | 14.98 | 46.44 | 52.37 | 0.59 | 4 | 4.02 | 3.05 | 1 | 1.63 | 1.60 | 1 | 1.05 | 1.11 |
| Luxembourg | 185 | 35 | 35.78 | 11.14 | 47.57 | 50.81 | 0.54 | 5 | 5.17 | 3.04 | 3 | 2.55 | 1.78 | 2 | 1.60 | 1.13 |
| Malta | 265 | 32 | 33.83 | 10.60 | 35.85 | 63.02 | 0.75 | 4 | 4.71 | 3.10 | 2 | 2.31 | 1.88 | 1 | 1.36 | 1.12 |
| Netherlands | 504 | 44 | 46.69 | 17.31 | 50.99 | 48.02 | 0.40 | 3 | 3.44 | 2.94 | 1 | 1.82 | 2.01 | 1 | 0.89 | 1.05 |
| Poland | 501 | 46 | 45.74 | 14.06 | 47.70 | 52.10 | 0.20 | 3 | 3.86 | 3.27 | 2 | 1.95 | 1.86 | 1 | 1.30 | 1.13 |
| Portugal | 502 | 48.50 | 46.50 | 13.61 | 46.81 | 52.59 | 0.40 | 3 | 3.89 | 2.90 | 1 | 1.76 | 1.74 | 1 | 1.29 | 1.07 |
| Romania | 504 | 45 | 45.18 | 14.44 | 45.63 | 53.17 | 0.60 | 5 | 4.90 | 2.69 | 1 | 1.92 | 1.93 | 1 | 1.18 | 1.13 |
| Slovakia | 502 | 45 | 45.95 | 14.70 | 48.61 | 51.39 | 0 | 5 | 4.60 | 3.10 | 3 | 2.36 | 1.69 | 1 | 1.15 | 1.05 |
| Slovenia | 504 | 44 | 44.72 | 13.33 | 50 | 49.60 | 0 | 4 | 4.54 | 2.93 | 2 | 2.04 | 1.87 | 1 | 1.07 | 1.08 |
| Spain | 505 | 48 | 46.51 | 13.83 | 43.96 | 55.45 | 0.40 | 4 | 4.17 | 2.79 | 1 | 1.76 | 1.79 | 1 | 1.13 | 1.04 |
| Sweden | 504 | 48 | 49.04 | 18.33 | 49.21 | 50.20 | 0.40 | 3 | 3.72 | 3.23 | 2 | 2.05 | 1.91 | 1 | 1.20 | 1.14 |
| **All countries** | 12829 | 45 | 46.03 | 15.32 | 47.45 | 51.80 | 0.43 | 4 | 4.29 | 3.02 | 2 | 1.98 | 1.85 | 1 | 1.15 | 1.11 |

We report here the total number of missing for age (*N* = 0), gender (*N* = 40), educational attainment (*N* = 87), and DJGLS-6 (*N* = 661), T-ILS (*N* = 407), and single-item loneliness (*N* = 522) scores.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 2**  *Loneliness Measures Included in the Survey* | | |  |  | |
| Measure | Subscale | General prompt | Question # | Question Content (Answer Options) | |
| T-ILS | N/A | Please indicate how often you feel each of the following: <Note:> Remember that your answers are anonymous and strictly confidential. | 1 | Feel that you lack companionship (Hardly ever or never; Some of the time; Often; Prefer not to say) | |
| T-ILS | N/A |  | 2 | Feel left out (Hardly ever or never; Some of the time; Often; Prefer not to say) | |
| T-ILS | N/A |  | 3 | Feel isolated from others (Hardly ever or never; Some of the time; Often; Prefer not to say) | |
| DJGLS-6 | Emotional | Please indicate for each of the statements, the extent to which they apply to your situation and the way you feel now.<Note:> Remember that your answers are anonymous and strictly confidential. | 1 | I experience a general sense of emptiness (Yes, More or less, No, Prefer not to say) | |
| DJGLS-6 | Emotional |  | 2 | I miss having people around (Yes, More or less, No, Prefer not to say) | |
| DJGLS-6 | Emotional |  | 3 | I often feel rejected (Yes, More or less, No, Prefer not to say) | |
| DJGLS-6 | Social |  | 4 | There are plenty of people I can rely on when I have problems (Yes, More or less, No, Prefer not to say) |
| DJGLS-6 | Social |  | 5 | There are many people I can trust completely (Yes, More or less, No, Prefer not to say) |
| DJGLS-6 | Social |  | 6 | There are enough people that I feel close to (Yes, More or less, No, Prefer not to say) |
| One-item | N/A |  | 1 | How much of the time, during the past 4 weeks, have you been feeling lonely? (All of the time, Most of the time, Some of the time, A little of the time, None of the time, Don’t know, Prefer not to say) |

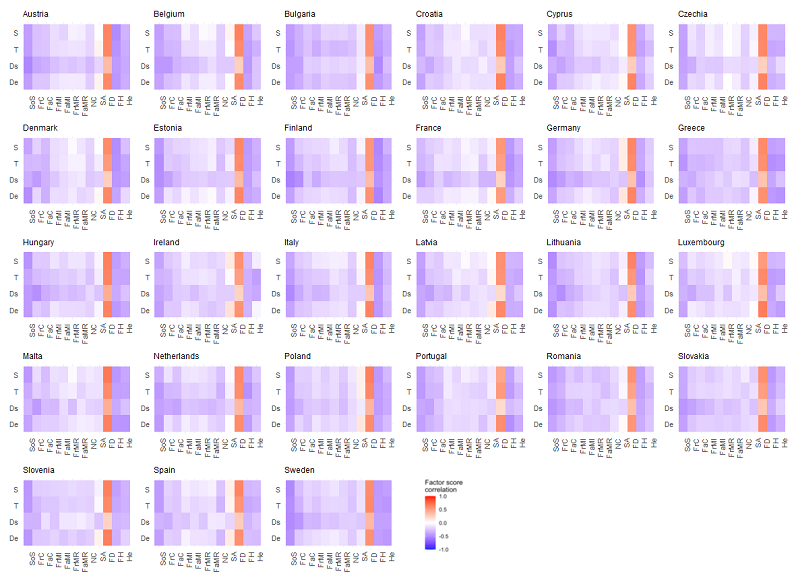


|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 3** |  |  |  |  |  |  |  |  |  |
| *Factor Structure Fits and Internal Consistencies of the DJGLS-6 and T-ILS* | | | | | | | |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  | DJGLS-6 (two-factor structure) | | | |  | T-ILS (one factor structure) | | | |
| Country | χ2 | CFI | RMSEA | ωemot | ωsocial | λ  Item 1 | λ  Item 2 | λ  Item 3 | ωtotal |
| Austria | 24.67 | 0.99 | 0.07 | 0.76 | 0.82 | 0.69 | 0.78 | 1.00 | 0.82 |
| Belgium | 61.89 | 0.98 | 0.12 | 0.71 | 0.79 | 0.80 | 0.86 | 0.98 | 0.86 |
| Bulgaria | 26.60 | 0.99 | 0.07 | 0.71 | 0.82 | 0.79 | 0.90 | 0.91 | 0.83 |
| Croatia | 59.97 | 0.98 | 0.12 | 0.74 | 0.79 | 0.77 | 0.88 | 0.95 | 0.83 |
| Cyprus | 15.07 | 1.00 | 0.06 | 0.75 | 0.86 | 0.75 | 0.85 | 0.95 | 0.82 |
| Czechia | 40.59 | 0.99 | 0.09 | 0.74 | 0.82 | 0.81 | 0.92 | 0.92 | 0.85 |
| Denmark | 43.69 | 0.99 | 0.10 | 0.84 | 0.84 | 0.80 | 0.92 | 0.92 | 0.85 |
| Estonia | 37.62 | 0.99 | 0.09 | 0.67 | 0.79 | 0.87 | 0.90 | 0.92 | 0.87 |
| Finland | 41.72 | 0.99 | 0.09 | 0.56 | 0.83 | 0.78 | 0.90 | 0.94 | 0.85 |
| France | 64.04 | 0.97 | 0.12 | 0.56 | 0.80 | 0.88 | 0.86 | 0.94 | 0.85 |
| Germany | 30.04 | 0.99 | 0.07 | 0.75 | 0.80 | 0.66 | 0.89 | 0.90 | 0.80 |
| Greece | 18.17 | 1.00 | 0.05 | 0.74 | 0.82 | 0.75 | 0.91 | 0.86 | 0.81 |
| Hungary | 36.63 | 0.99 | 0.09 | 0.68 | 0.80 | 0.84 | 0.89 | 0.96 | 0.86 |
| Ireland | 20.41 | 0.99 | 0.06 | 0.72 | 0.79 | 0.86 | 0.80 | 0.82 | 0.80 |
| Italy | 37.32 | 0.99 | 0.09 | 0.76 | 0.79 | 0.81 | 0.92 | 0.95 | 0.86 |
| Latvia | 37.37 | 0.99 | 0.09 | 0.81 | 0.81 | 0.81 | 0.91 | 0.89 | 0.84 |
| Lithuania | 2.96 | 1.00 | 0.00 | 0.82 | 0.84 | 0.81 | 0.80 | 0.85 | 0.77 |
| Luxembourg | 13.83 | 0.99 | 0.07 | 0.70 | 0.79 | 0.83 | 0.84 | 0.71 | 0.77 |
| Malta | 14.43 | 0.99 | 0.06 | 0.70 | 0.79 | 0.80 | 0.88 | 0.94 | 0.85 |
| Netherlands | 20.23 | 1.00 | 0.06 | 0.76 | 0.79 | 0.80 | 0.91 | 0.96 | 0.86 |
| Poland | 20.38 | 1.00 | 0.06 | 0.86 | 0.85 | 0.86 | 0.88 | 0.88 | 0.84 |
| Portugal | 29.11 | 0.99 | 0.07 | 0.74 | 0.78 | 0.77 | 0.81 | 0.95 | 0.81 |
| Romania | 79.90 | 0.98 | 0.14 | 0.56 | 0.84 | 0.75 | 0.92 | 0.90 | 0.83 |
| Slovakia | 22.84 | 1.00 | 0.06 | 0.68 | 0.85 | 0.73 | 0.84 | 0.88 | 0.79 |
| Slovenia | 37.56 | 1.00 | 0.09 | 0.85 | 0.82 | 0.84 | 0.84 | 0.97 | 0.85 |
| Spain | 45.78 | 0.99 | 0.10 | 0.68 | 0.83 | 0.80 | 0.85 | 0.94 | 0.83 |
| Sweden | 27.94 | 0.99 | 0.07 | 0.76 | 0.85 | 0.86 | 0.90 | 0.94 | 0.87 |
| **All countries** | **683.70** | **0.99** | **0.08** | **0.73** | **0.82** | **0.79** | **0.88** | **0.92** | **0.83** |

*Note*. We decided on the factor structure after reviewing the exploratory and confirmatory analyses.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **Table 4**  *Results of the Multigroup Confirmatory Factor Analyses on the Unraveled Clusters* | | | | | | | | |  |  |  |  |  |  |  |  |
|  |  | |  |  |  | |  |  |  | |  |  |  | | | | | |
|  | Configural model | | | |  | Metric Model | | |  | Scalar model | | |  | | | | | |
| Cluster ID | χ2  (*df*, *p*) | | CFI | RMSEA | χ2  (*df*, *p*) | | CFI (ΔCFI) | RMSEA (ΔRMSEA) | χ2  (*df*, *p*) | | CFI (ΔCFI) | RMSEA (ΔRMSEA) | Decision about invariance | | | | | |
| A | 223  (32, <.001) | | 0.98 | 0.11 | . | | . | . | . | | . | . | No invariance | | | | | |
| B | 510  (128, <.001) | | 0.99 | 0.08 | 658  (188, <.001) | | 0.99 (0) | 0.08 (0) | 789  (248, <.001) | | 0.99 (0) | 0.07 (.01) | Scalar | | | | | |
| C | 177  (56, <.001) | | 1 | 0.07 | 236  (80, <.001) | | 0.99 (.01) | 0.06 (.01) | 278  (104, <.001) | | 0.99 (0) | 0.06 (0) |  | | | | | |

*Note.* Cluster A: Estonia, Finland, France, Romania. Cluster B: Belgium, Bulgaria, Croatia, Cyprus, Czechia, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, Portugal, Slovakia, Slovenia, Spain. Cluster C: Austria, Denmark, Latvia, Lithuania, Netherlands, Poland, Sweden.



*Figure 1.* Heatmap of the correlations between loneliness measures and relevant correlates. De = DJGLS-6 emotional, Ds = DJGLS-6 social, T = T-ILS, S = Single-item measure, SoS = Social support, FrC = Friends closeness, FaC = Family closeness, FrMI = Friends meet in-person, FaMI = Family meet in-person, FrMR = Friends meet remote, FaMR = Family meet remote, NC = Neighbours contact, SA = Social activities, FD = Feeling depressed, FH = Feeling happy, He = Health.

**Appendix A**

Predictions for the confirmatory fold across countries, for each loneliness measure and each measurement property, as derived from analyses on the exploratory fold.

*Note.* The plus (**+**) sign indicates that the measurement property meets the minimum standards, as outlined by the thresholds in the “Interpretation given different outcomes” column of the design table.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | DJGLS**-**6 (two factors) | | | | T**-**ILS (one factor) | | | | Single**-**item |
|  | Factor structure | Internal consistency | Measurement invariance | Construct validity | Factor structure | Internal consistency | Measurement invariance | Construct validity | Construct validity |
| Austria | **+** | **+** | Scalar invariance across countries in cluster B (Belgium, Bulgaria, Croatia, Cyprus, Czechia, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, Portugal, Slovakia, Slovenia, Spain); and cluster C (Austria, Denmark, Latvia, Lithuania, Netherlands, Poland, Sweden); No configural invariance across countries in cluster A (Estonia, Finland, France, Romania). | **+** | **-** | **+** | Scalar invariance across the 27 countries. | **+** | **+** |
| Belgium | **-** | **+** | **+** | **+** | **+** | **+** | **+** |
| Bulgaria | **+** | **+** | **+** | **+** | **+** | **+** | **+** |
| Croatia | **-** | **+** | **+** | **+** | **+** | **-** | **+** |
| Cyprus | **+** | **+** | **-** | **+** | **+** | **-** | **-** |
| Czechia | **-** | **+** | **+** | **+** | **+** | **-** | **-** |
| Denmark | **-** | **+** | **+** | **+** | **+** | **+** | **+** |
| Estonia | **-** | **+** | **+** | **+** | **+** | **+** | **+** |
| Finland | **-** | **-** | **+** | **+** | **+** | **+** | **+** |
| France | **-** | **-** | **+** | **+** | **+** | **+** | **+** |
| Germany | **+** | **+** | **+** | **-** | **+** | **+** | **+** |
| Greece | **+** | **+** | **+** | **+** | **+** | **+** | **+** |
| Hungary | **-** | **+** | **+** | **+** | **+** | **+** | **+** |
| Ireland | **+** | **+** | **+** | **+** | **+** | **+** | **+** |
| Italy | **-** | **+** | **+** | **+** | **+** | **+** | **-** |
| Latvia | **-** | **+** | **+** | **+** | **+** | **+** | **-** |
| Lithuania | **+** | **+** | **+** | **+** | **+** | **+** | **+** |
| Luxembourg | **+** | **+** | **-** | **+** | **+** | **-** | **-** |
| Malta | **+** | **+** | **+** | **+** | **+** | **-** | **-** |
| Netherlands | **+** | **+** | **+** | **+** | **+** | **+** | **-** |
| Poland | **+** | **+** | **+** | **+** | **+** | **+** | **+** |
| Portugal | **+** | **+** | **+** | **+** | **+** | **+** | **+** |
| Romania | **-** | **-** | **+** | **+** | **+** | **+** | **+** |
| Slovakia | **+** | **+** | **+** | **+** | **+** | **+** | **+** |
| Slovenia | **-** | **+** | **+** | **+** | **+** | **+** | **+** |
| Spain | **-** | **+** | **+** | **+** | **+** | **+** | **-** |
| Sweden | **+** | **+** | **+** | **+** | **+** | **+** | **+** |

1. Note that the JRC’s EU 27 survey was conducted online with a non-probability (quota) based sample and 16+, whereas the Gallup Survey was conducted with a probability sample, face-to-face or via telephone, and 15+. Sampling and survey mode differences could therefore maybe explain a part of the difference. [↑](#footnote-ref-2)
2. We did not dichotomize the single-item loneliness variable as is sometimes done, as dichotomization of continuous variables “has only negative consequences and should be avoided” (Irwin & McClelland, 2003). [↑](#footnote-ref-3)
3. While it is generally preferable to allocate a higher proportion of data for training, we chose to split the data in half to ensure approximately 500 participants per country per fold. This decision aligns with research findings that suggest 500 is a minimum ideal number of participants for factor analyses under various circumstances (MacCallum et al., 1999). [↑](#footnote-ref-4)