**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, and Hans IJzerman.

**Abstract**

Loneliness has been associated with a number of 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* representing 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? | Based on prior research, we suspect that the model fits are sufficient. For the DJGLS-6, we predict a two-factor solution across countries in the European Union. For the T-ILS, we predict a one-factor solution across countries in the European Union.  Given that no comprehensive data exists on its factor structure in samples from the European Union, we are not very certain of these a priori hypotheses. | We will partition the data from the EU Loneliness Survey (*N* = 25,646, representing 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 using a combination of exploratory and confirmatory factor analyses. We will run exploratory factor analyses to search for the most appropriate structure of the measure. In parallel, we will run confirmatory factor analyses on the factor structures usually employed in the literature (i.e., a two-factor structure for the DJGLS-6, and a one-factor for the T-ILS).  Following these analyses in the exploratory fold, we will decide – per country – what the factor structure of both scales should be and test these in the confirmatory fold using confirmatory factor analyses. | A sample size of n=500 has been found to be the minimum ideal number of participants for factor analyses under various conditions (MacCallum et al., 1999). | 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).  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, and won't conduct further tests (i.e., internal consistency, measurement invariance, and construct validity) on the countries where the scale is inadequate | 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? | A priori, we expect that reliability is sufficient for the two subscales of the DJGLS-6 and for the T-ILS.  Given that no comprehensive data exists on its factor structure in samples from the European Union and that typically the wrong reliability metric has been used for these scales, we are not very certain of these a priori hypotheses. | We will partition the data from the EU Loneliness Survey (*N* = 25,646, representing 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 Omega.  We will report the Omega unidimensional in case of a one-factor structure, or the Omega hierarchical in case of a n-factors structure.  Following these analyses in the exploratory fold, we will preregister the Omega coefficients with 95% CI obtained for each country, and try to replicate them in the confirmatory fold. | 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). | Recommendations regarding minimum values for internal consistency are sparse, with 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 considered ω values ≥ .60 as indicators of sufficient internal consistency given the short length of the DJGLS-6 and T-ILS.  A subscale or scale demonstrating an internal consistency lower than .60 would suggest that scores to the measure may not reliably reflect the true level of loneliness in the individuals, resulting in an imprecise assessment. In such a case, we won’t conduct further tests (i.e., measurement invariance, nomological net) on the measure. | For both the two subscales of the DJGLS-6 and the T-ILS, if we find insufficient internal consistency for a given country, 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? | As very little data exists on measurement invariance across the European Union, we don’t have a priori hypotheses at this stage of the research. | We will partition the data from the EU Loneliness Survey (*N* = 25,646, representing 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 across the 27 EU member states using a three-phased approach. First, we will assess measurement invariance across countries using multigroup factor analyses. In case we find the measure to be non-invariant at any level (i.e., configural, metric, or scalar) we will then run mixture multigroup factor analysis to detect clusters of countries invariant at the scalar level. Following this, we will assess measurement invariance in the clusters unraveled using multigroup confirmatory factor analysis again.  Following these analyses in the exploratory fold, in case we managed to establish scalar invariance, we will preregister the list of invariant countries, and assess measurement invariance in these countries in the confirmatory fold, using multigroup confirmatory factor analysis directly. | 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 will establish configural invariance with the same criteria as for the factor structure property (i.e., CFI values ≥ .90 and RMSEA values ≤ .08);  Following guidelines from Rutkowski & Svetina (2014), we will establish 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 we use mixture multigroup factor analysis, we will select the best clustering solution using the Convex Hull procedure (minimized scree ratio and visual detection of an elbow on the scree plot) and Bayesian Information Criterion (minimized BIC\_G value).  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 suffice? | Based on prior research, we suspect that the DJGLS-6, and T-ILS will show great construct validity across the European Union. However, given that no comprehensive data exists in samples from the European Union, we are not very certain of these priori hypotheses.  We don’t have a priori hypotheses for the single-item measure. | We will partition the data from the EU Loneliness Survey (*N* = 25,646, representing 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 zero-order correlation coefficients with various items, for each country separately.  Following these analyses in the exploratory fold, we will preregister the correlation coefficients with 95% CI obtained for each country, and try to replicate them in the confirmatory fold. | Our sample sizes will be larger than the threshold of n=250 at which correlations appear to stabilize (Schönbrodt & Perugini, 2013). | We will consider the measures to have sufficient construct validity if they are well integrated into their nomological network of variables consisting of indicators of social connectedness, emotions, and health.  At least two-thirds of the 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 correlation with the indicator of negative emotion, and negative correlations with the indicators of social connectedness, positive emotion, and health.  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) launched a commission on social connection, the US former 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). This shift in strategic priority 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 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 Citizens in the European Union 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). 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). Unwanted 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. Unwanted 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 unwanted 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 European Union. 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. 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 and health conditions (Elovainio et al. (2017; Perissinotto et al., 2012). Similarly, while Valtorta et al. (2018) find that loneliness, but not social isolation, increases the risk of heart disease and stroke, 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 has been defined as subjective social isolation (Holt-Lunstad et al., 2015) or as the negative experience caused by a discrepancy between one’s desired and achieved social relations (Perlman & Peplau, 1981). Loneliness is most commonly 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 the relationship provisions of a network of contacts, and *emotional loneliness*, the type of loneliness that arises when a person perceives to lack the relationship provisions of close emotional attachments (Maes et al., 2022). At the heart of all of 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 longer-term 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 JRC EU-wide loneliness measurement [which we currently study] and the Meta-Gallup State of Social Connection study; Gallup, 2022) differs – on average – by 4.04% in 23 EU member states, with some estimates differing by as much as 8 percentage points.[[1]](#footnote-1) 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 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). While single-item measures are cost-effective and easy to deploy for the monitoring of larger populations, 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, single-item measures are typically associated with higher measurement error with a concomitant less precise assessment of the underlying construct (Allen et al., 2022). It is further difficult to establish to which degree people from different groups (e.g., EU member states) compare, as measurement invariance tests cannot be applied to single-item measures (Chen, 2008; Greiff & Scherer, 2018; Meredith, 1993).

On the other hand, composite indexes typically provide more robust 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 commonly 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.

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 European Union**

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 gap remains if one were to use these measures for population monitoring.

Recent reviews of the available evidence of internal structure consistency 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 European Union. 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 European Union, 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 Alpha, which often yields biased estimates of internal consistency due to the assumption of tau equivalence that rarely holds (Flora, 2020; McNeish, 2018; Sijtsma, 2009).

Furthermore, while measurement invariance 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). Regional 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 meaningless. Of course, for single-item measures, no possibilities to test for factor structure, measurement invariance, or internal consistency exist.

Similar gaps exist for these measures’ construct validity which is identified through the nomological network. 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 were 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 great 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 networks, 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. In order to do so, we relied on data from the *EU Loneliness Survey*, an EU-wide survey conducted by the *Joint Research Centre* and totaling 25,646 respondents representing the 27 EU member states.

Based on previous research, we expected the DJGLS-6 to provide a sufficient 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 general loneliness with sufficient internal consistency. 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 (exact predictions will be sharpened – to the level of shape and CI of the correlations – after the analyses in the exploratory fold). 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.

**Methods**

**Participants**

The Joint Research Centre (represented by Elizabeth Casabianca and Béatrice d’Hombres in this report) recruited respondents of the *EU Loneliness Survey* (*N* = 25,646) 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. Quotas based on the population of each Member State were used for sample selection. They reflected the target population in terms of age, gender, educational attainment, and NUTS region of residence based on available data from Eurostat. Moreover, *ex-post* 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.

**Data collection**

Data collection occurred between November and December 2022. A Consortium consisting of LE Europe, Ipsos and VVA Market Research devised the sampling strategy and selected the survey provider based on the JRC data collection requirements. The Consortium selected CINT, a single network of panels that covered all EU 27 Member States, to collect the data. CINT was selected after assessing its geographical coverage and their ability of sourcing unsurveyed respondents. The recruitment and sampling strategy was based on the use of panel providers with established online consumer panels in all EU 27 Member States.

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.

Eligible participants received invitations to fill the online survey, for an average completion time of 28 minutes. 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**

The selection of the measures and items was based on their inclusion in social surveys at the European and international level, such as the ESS (European Social Survey) and SHARE (Survey on Health Ageing and Retirement in Europe). Minor changes to the wording of some questions were made following feedback from the Consortium and results of cognitive testing.

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 (ωsocial = XX) and emotional loneliness (ωemotional = XX). 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 (ωu-cat = .XX). 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.

A number of 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 child experiences (5 items; e.g., “When growing up, have you always lived with both of your parents?”). We selected a number of measures to be part of the nomological network analyses. Those consisted of indicators of social connectedness, indicators of positive and negative emotions, and an indicator of health. The indicators of social connectedness comprised a composite measure of social support (4 items; e.g., “how often is available someone to share your most private worries and fears with”; ωu-cat = .XX) and single-item measures of the participants closeness in relationship with friends and family, occurrences of in-person and remote (virtual or telecommunication) meetings with friends and family, occurrences of contacts with neighbours, and frequency of participation in social activities. Indicators of positive and negative emotion comprised single-item measures of happiness and depressed feelings, and the indicator of health assessed the participants self-perceived health. The full survey is 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, employed a fixed random seed to partition the dataset into two folds—exploratory and confirmatory—of equal sample sizes[[2]](#footnote-2). 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 then pre-registered the findings and the resulting hypothesis prior to testing them in our confirmatory fold.

For the DJGLS-6 and T-ILS, we (a) determined their optimal factor structure through exploratory factor analyses and subsequently validated it through confirmatory factor analyses, 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 Omega, (c) assessed their measurement invariance properties through a combination of multigroup confirmatory factor analyses and mixture multigroup factor analyses. 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 X.X.X; R Core Team, 2022). All of 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 a combination of a judgment of theoretical parsimony and results from parallel analysis (Horn, 1965) and Empirical Kaiser Criterion (Braeken & Van Assen, 2017). Parallel analysis and Empirical Kaiser Criterion both retain a factor structure when its eigenvalue is greater than the mean eigenvalue from its random counterpart. In case these methods yielded inconsistent results, we favored the factor structure returned by the Empirical Kaiser Criterion (while still balancing the results with theoretical parsimony). The Empirical Kaiser Criterion tends to outperform parallel analysis when used on short scales with correlated dimensions (Braeken & Van Assen, 2017). 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. As a consequence, we did not use *p*-values as indicators when evaluating the fit of the factor structures. 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; very 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).

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). More specifically, we either reported the Omega unidimensional (ωu-cat) in case of a one-factor structure, or the Omega hierarchical (ωh-cat) in case of a n-factors structure. 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 on the DJGLS-6 and T-ILS across countries in the EU, 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). 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. More specifically, we used the mixmgfa 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.

***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 correlations between the loneliness measures with composite measures and items concurrently administered in the EU Loneliness Survey, for each country separately. We computed zero-order correlation coefficients to quantify the relationship between the three loneliness measures with indicators of social connectedness, indicators of emotions, and an indicator of health.

We considered the loneliness measures to show sufficient construct validity in cases where at least two-thirds of the 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 alpha threshold adjusted to .004), and a | *r |* ≥ .010. We expected positive correlations between the loneliness scores and the indicator of negative emotion, and negative correlations between the loneliness scores and the indicators of social connectedness, positive emotion, and health. In addition, we computed correlation coefficients to quantify the relationship between the three loneliness measures (i.e., the DJGLS-6, T-ILS, and single-item measure of loneliness).

**Results**

**Results from the exploratory dataset**

In summary, [only the DJGLS-6/only the T-ILS/both the DJGLS-6 and T-ILS/neither the DJGLS-6 nor the T-ILS] provided evidence of sufficient measurement properties on factor structure, internal consistency, measurement invariance, and construct validity. More specifically, the DJGLS-6 provided a [poor/acceptable/very good] fit for a [one/two] factor structure for XX countries, [insufficient/sufficient] internal consistency for XX countries, [provided/failed to provided] evidence of measurement invariance across [the 27 EU member states/n different clusters of countries], and [provided/failed to provide] evidence of sufficient construct validity for XX countries. The T-ILS provided a [poor/acceptable/very good] fit for a one factor structure for XX countries, [insufficient/sufficient] internal consistency for XX countries, [provided/failed to provide] evidence of measurement invariance across [the 27 EU member states/n different clusters of countries], and [provided/failed to provide] evidence of sufficient construct validity for XX countries. The one–item measure of loneliness [provided/failed to provide] evidence of sufficient construct validity for XX countries.

***Factor Analyses and Internal Consistency***

Following exploratory and confirmatory factor analyses, we decided to retain a [one/two] factor structure for the DJGLS-6, and a one factor structure for the T-ILS. The DJLGS-6 provided [a poor/an acceptable/a very good] fit to a [one/two] factor structure for XX countries with [sufficient/insufficient] internal consistency for XX countries. the T-ILS provided [a poor/an acceptable/a very good] fit to a one factor structure for XX countries with [sufficient/insufficient] internal consistency for XX countries. Table 2 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 [one/two] factor structure was the most appropriate for the DJGLS-6 across the 27 EU member states. We found this [one/two] factor model to provide [a poor/an acceptable/a very good] fit to the data (χ² = XXX, *p* = .XXX, CFI *=* .XXX, RMSEA = XXX, CI 90% [XXX, XXX]) with [sufficient/insufficient] internal consistency ([ωh-cat respectively .XX, .XX/ωu-cat = XX]). 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 found the two-factor model to provide [a poor/an acceptable/a very good] fit to the data (χ² = XXX, *p* = .XXX, CFI *=* .XXX, RMSEA = XXX, CI 90% [XXX, XXX]) with [sufficient/insufficient] internal consistency (ωsocial = .XX, ωemotional = .XX). [Here, we will make a preliminary decision as to which factor structure we will keep for the measurement invariance and nomological network analyses, balancing between theoretical parsimony and model fit. We may revisit this decision in case we encounter problems with the measurement invariance and/or nomological network analyses, but will finalize before pre-registration]. 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 2.

**T-ILS.** As the T-ILS is a three-item scale, the seemingly only possible structure was a one-factor structure, corresponding to the factor structure employed in the literature. We directly tested the model fit of this structure across the 27 EU member states, using confirmatory factor analyses. We found the model to provide [a poor/an acceptable/a very good] fit to the data (χ² = XXX, *p* = .XXX, CFI *=* .XXX, RMSEA = XXX, CI 90% [XXX, XXX]) with [sufficient/insufficient] internal consistency (ωu-cat = .XX). We report the model fit indices and internal consistency obtained across the 27 EU member states and for each country separately in Table 2.

***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 at the [configural/metric/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.] In sum, [here we will summarize the evidence of measurement invariance we found. In case we found evidence of scalar invariance for the scales, we will insert one Figure per scale that will depict the clusters of countries in which scalar invariance holds].

**DJGLS-6**. To establish configural invariance of the DJGLS-6, we first assessed if the [one/two] factor structure of the measure provided an acceptable fit for the 27 EU member states using multigroup confirmatory factor analysis. The [one/two] factor structure provided [a poor/an acceptable/a very good] fit across the 27 EU member states (χ² = XXX, *p* = .XXX, CFI *=* .XXX, RMSEA = XXX, CI 90% [XXX, XXX]), which suggests that configural invariance [holds/does not hold] across the countries.

[The following paragraph applies in case configural invariance holds]. To establish metric invariance of the DJGLS-6, we then compared the performance of a model that imposed equal factor loadings across countries (i.e., a metric model) to the performance of the configural model, using multigroup confirmatory factor analysis. The metric model [performed significantly worse/did not perform significantly worse] than the configural model (χ² = XXX, *p* = .XXX, CFI *=* .XXX, RMSEA = XXX, CI 90% [XXX, XXX]). Differences between the models fit were [smaller/bigger] than the cut-off values we set for measurement invariance (ΔCFI *=* .XXX, ΔRMSEA= XXX), which suggests that metric invariance [holds/does not hold] across the countries.

[The following paragraph applies in case metric invariance holds]. To establish scalar invariance of the DJGLS-6, 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/did not perform significantly worse] than the metric model (χ² = XXX, *p* = .XXX, CFI *=* .XXX, RMSEA = XXX, CI 90% [XXX, XXX]). Differences between the models fit were [smaller/bigger] than the cut-off values we set for measurement invariance (ΔCFI *=* .XXX, ΔRMSEA= XXX), which suggests that scalar invariance [holds/does not hold] across the countries.

[The following two paragraphs apply in case configural/metric/scalar invariance doesn’t hold]. As [configural/metric/scalar] 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 [one/two] factor structure of the DJGLS-6 across the 27 EU member states by using the *mixmgfa* 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/The Convex Hull procedure] suggested a [2/3/4/5/6] clusters solution [whereas the BIC\_G criterion suggested a [2/3/4/5/6] clusters solution]. After further inspection of the Convex Hull plot, we decided to retain a [2/3/4/5/6] clusters solution as [no clear elbow could be detected on the plot/a clear elbow could be detected on the plot around the n clusters solution].

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 3a. Overall, the results of these analyses were [consistent/inconsistent] with the conclusions drawn from the mixture multigroup factor analysis.

**T-ILS.**To establish configural invariance of the T-ILS, we first assessed if the one factor structure of the measure provided an acceptable fit for the 27 EU member states using multigroup confirmatory factor analysis. The one factor structure provided [a poor/an acceptable/a very good] fit across the 27 EU member states (*χ²* = XXX, *p* = .XXX, *CFI =* .XXX, *RMSEA* = XXX, CI 90% [XXX, XXX]), which suggests that configural invariance [holds/does not hold] across the countries.

[The following paragraph applies in case configural invariance holds]. To establish metric invariance of the T-ILS, we then compared the performance of a model that imposed equal factor loadings across countries (i.e., a metric model) to the performance of the configural model, using multigroup confirmatory factor analysis. The metric model [performed significantly worse/did not perform significantly worse] than the configural model (*χ²* = XXX, *p* = .XXX, *CFI =* .XXX, *RMSEA* = XXX, CI 90% [XXX, XXX]). Differences between the models fit were [smaller/bigger] than the cut-off values we set for measurement invariance (ΔCFI *=* .XXX, ΔRMSEA= XXX), which suggests that metric invariance [holds/does not hold] across the countries.

[The following paragraph applies in case metric invariance holds]. 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/did not perform significantly worse] than the metric model (*χ²* = XXX, *p* = .XXX, *CFI =* .XXX, *RMSEA* = XXX, CI 90% [XXX, XXX]). Differences between the models fit were [smaller/bigger] than the cut-off values we set for measurement invariance (ΔCFI *=* .XXX, ΔRMSEA= XXX), which suggests that scalar invariance [holds/does not hold] across the countries.

[The following two paragraphs apply in case configural/metric/scalar invariance doesn’t hold]. As [configural/metric/scalar] 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 one factor structure of the T-ILS across the 27 EU member states by using the *mixmgfa* 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/The Convex Hull procedure] suggested a [2/3/4/5/6] clusters solution [whereas the BIC\_G criterion suggested a [2/3/4/5/6] clusters solution]. After further inspection of the Convex Hull plot, we decided to retain a [2/3/4/5/6] clusters solution as [no clear elbow could be detected on the plot/a clear elbow could be detected on the plot around the n clusters solution].

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 3b. Overall, the results of these analyses were [consistent/inconsistent] with the conclusions drawn from the mixture multigroup factor analysis.

***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 case we found at least two-thirds of the correlations significant at the .004 level and in the expected direction with a | *r* |≥ .10, we will consider the measure to display sufficient construct validity for a given country. We will synthesize the countries that reached the criteria of sufficient construct validity, for each measure.]. In addition, we found the three measures to be [here we will describe the correlations between the loneliness measures, averaged across the 27 countries and with their ranges]. Table 4A-C summarizes all the different correlation coefficients obtained for each country, for the DJGLS-6, T-ILS, and single-item measure of loneliness, respectively.

**Table 4.** Nomological Networks of the Three Loneliness Measures

[TABLE 4 TO BE INSERTED HERE]

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

We pre-registered the findings obtained from the analyses conducted on the exploratory dataset and aimed to replicate and validate them in the confirmatory dataset [Note that more exact predictions will be added after the exploratory fold is analyzed]. In case model fit in the confirmatory factor analyses or reliability was insufficient in a given country, we did not conduct further tests in the confirmatory fold.

More specifically, we pre-registered (a) the factor structure (to assess with confirmatory factor analysis directly) and internal consistency of [Included if model fit and reliability were sufficient: the DJGLS-6 [one/two]-factor structure for XX countries, and the T-ILS one-factor structure for XX countries], [included if measures were invariant: (b) the measurement invariance properties (to assess with multigroup confirmatory factor analyses directly) obtained for the DJGLS-6 ([described here]), and for the T-ILS ([described here]), and (c) [if model fit and reliability were sufficient: the correlations with confidence intervals obtained through the nomological network analyses, for the DJGLS-6 for XX countries, for the T-ILS for XX countries, and for the single-item measure of loneliness for XX countries].

We provided our measurement invariance and country-by-country predictions derived from the exploratory dataset with the conclusions from the confirmatory dataset at our OSF Page: <https://osf.io/5ecx3/>.

***Factor analyses and internal consistency***

We [replicated/partially replicated/failed to replicate] the factor structure and internal consistency properties of the DJGLS-6 and T-ILS obtained on the exploratory dataset 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 analyses conducted on the exploratory dataset/Contrary to the analyses conducted on the exploratory dataset], the DJLGS-6 provided [a poor/an acceptable/a very good] fit to a [one/two] factor structure for XX countries out of XX, with [sufficient/insufficient] internal consistency for XX countries out of XX.

**T-ILS.** [In line with the analyses conducted on the exploratory dataset/Contrary to the analyses conducted on the exploratory dataset], the T-ILS provided [a poor/an acceptable/a very good] fit to a one factor structure for XX countries out of XX, with [sufficient/insufficient] internal consistency for XX countries out of XX.

***Measurement invariance***

We [replicated/partially replicated/failed to replicate] the measurement invariance properties of the DJGLS-6 and T-ILS obtained on the exploratory dataset.

**DJGLS-6.** [In line with the analyses conducted on the exploratory dataset/Contrary to the analyses conducted on the exploratory dataset], the DJLGS-6 [provided/did not provide] evidence of measurement invariance [measurement invariance properties described here].

**T-ILS.** [In line with the analyses conducted on the exploratory dataset/Contrary to the analyses conducted on the exploratory dataset], the T-ILS [provided/did not provide] evidence of measurement invariance [measurement invariance properties described here].

***Construct Validity***

We [replicated/partially replicated/failed to replicate] the construct validity property of the DJGLS-6, T-ILS, and single-item measure of loneliness obtained on the exploratory dataset. Out of all the correlation coefficients we pre-registered for each measure, we replicated XX out of XX for the DJGLS-6, XX out of XX for the T-ILS, and XX out XX for the single-item measure of loneliness.[[3]](#footnote-3)

**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 | Median | Mean | SD | Male | Female | Other | Median | Mean | SD | Median | Mean | SD | Median | Mean | SD |
| Austria | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Belgium | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Bulgaria | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Croatia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Cyprus | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Czechia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Denmark | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Estonia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Finland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| France | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
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| Hungary | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Ireland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Italy | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Latvia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Lithuania | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Luxembourg | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Malta | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Netherlands | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Poland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Portugal | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Romania | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Slovakia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Slovenia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Spain | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Sweden | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| **All countries** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** |

*Note*. Descriptive statistics for the exploratory fold [we will report the statistics on all data upon completion on the project]. We report here the total number of missing for age (*N* = XX), gender (*N* = XX), educational attainment (*N* = XX), and DJGLS-6 (*N* = XX), T-ILS (*N* = XX), and single-item loneliness (*N* = XX) scores.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 2** |  |  |  |  |  |  |  |  |  |  |
| *Factor Structure Fits and Internal Consistencies of the DJGLS-6 and T-ILS* | | | | | | | |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  | DJGLS-6 ([one/two] factor structure) | | | |  | T-ILS (one factor structure) | | | |  |
| Country | χ2 (*p*-value) | CFI | RMSEA | Ω | Ω 95% CI | χ2 (*p*-value) | CFI | RMSEA | Ω | Ω 95% CI |
| Austria | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Belgium | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Bulgaria | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Croatia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Cyprus | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Czechia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Denmark | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Estonia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Finland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| France | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Germany | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Greece | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Hungary | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Ireland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Italy | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Latvia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Lithuania | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Luxembourg | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Malta | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Netherlands | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Poland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Portugal | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Romania | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Slovakia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Slovenia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Spain | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Sweden | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| **All countries** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** |

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

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 3a** |  |  |  |  |  |  |  |  |  |
| *Results of the Measurement Invariance Tests Conducted on the Clusters Unraveled by the Mixture Multigroup Factor Analyses for the*  *DJGLS-6* | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |
|  | Configural model | | | Metric Model | | Scalar model | |  |  |
| Cluster ID | χ2 (*p*-value) | CFI | RMSEA | χ2 (*p*-value) | Metric Δ fits | χ2 (*p*-value) | Scalar Δ fits | Decision about invariance | Convergence with MMG-FA |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |

*Note.* [Here we will describe the countries inside each cluster ID]

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 3b** | |  |  |  |  |  |  |  |  |
| *Results of the Measurement Invariance Tests Conducted on the Clusters Unraveled by the Mixture Multigroup Factor Analyses for the*  *T-ILS* | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |
|  | Configural model | | | Metric Model | | Scalar model | |  |  |
| Cluster ID | χ2 (*p*-value) | CFI | RMSEA | χ2 (*p*-value) | Metric Δ fits | χ2 (*p*-value) | Scalar Δ fits | Decision about invariance | Convergence with MMG-FA |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |

*Note.* [Here we will describe the countries inside each cluster ID]

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tables 4A-C** |  |  |  |  |  |  |  |  |  |  |  |  |
| *Nomological Networks of the [LONELINESS MEASURE NAME]* | | | |  |  |  |  |  |  |  |  |  |
|  | indicators of social connectedness | | | | | | | | | indicators of emotions | | indicator of health |
| Country | social support | closeness with friends | closeness with family | meetings with friends (face) | meetings with friends (remote) | meetings with family (face) | meetings with family (remote) | contacts with neighbours | frequency of social activity | depressed feelings | happiness feelings | perceived health |
| Austria | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Belgium | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Bulgaria | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Croatia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Cyprus | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Czechia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Denmark | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Estonia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Finland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| France | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Germany | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Greece | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Hungary | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Ireland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Italy | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Latvia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Lithuania | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Luxembourg | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Malta | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Netherlands | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Poland | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Portugal | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Romania | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Slovakia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Slovenia | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Spain | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| Sweden | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX | XX |
| **All countries** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** | **XX** |

*Note*. [We will insert one table for each measure]

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 potentially explain a part of the difference. [↑](#footnote-ref-1)
2. 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-2)
3. Successful replication, for the nomological network means an overlapping confidence interval and a similar shape of the relationship (e.g., linear or curvilinear). [↑](#footnote-ref-3)