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Posttraumatic stress disorder and loneliness are associated over time: A longitudinal study on PTSD symptoms and loneliness, among older adults

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ABSTRACT

Loneliness has a pernicious effect on mental health in later life and is likely to have a bidirectional relationship with psychopathology. However, longitudinal research examining loneliness and posttraumatic stress symptoms among older adults is scarce. This study aimed to examine the longitudinal relationship between different types of loneliness (social and emotional) and posttraumatic stress symptoms. Using two waves of an older adult sample (n = 1,276) from the Longitudinal Aging Study Amsterdam (LASA), this longitudinal relationship was examined using a multivariate two wave-latent change score (2W-LCS) model. There were significant, however, very small increases in both posttraumatic stress symptoms and emotional loneliness over time, whereas, average social loneliness scores did not significantly increase/decrease over time. Changes in both social (β = .16) and emotional loneliness (β = .15) were associated with small changes in posttraumatic stress symptoms, consistent with the existence of a longitudinal association between the constructs, net of covariate effects. Results provide evidence of the existence of a longitudinal association between subtypes of loneliness and posttraumatic stress symptoms, among older adults. Results have implications for clinicians who should identify individuals at risk of developing posttraumatic stress symptoms, and for the theory of both posttraumatic stress disorder and loneliness.

1. Introduction

Loneliness is a distressing psychological experience that occurs when an individual feels their social connectedness to be insufficient (Peplau and Perlman, 1982). It has been conceptualised as a unidimensional, and as a multidimensional construct that is characterised by 'emotional loneliness' (emotional loneliness; lack, or absence, of intimate relationships and close attachments) and 'social loneliness' (social loneliness; desire to have a wider engaging social network that can provide a sense of belonging and companionship) (de Jong Gierveld and van Tilburg, 2006). Loneliness is common among older adults (Ong et al., 2016) and while it is not unique to the ageing population (Qualter et al., 2015), can often arise in later life (Cohen-Mansfield et al., 2016). This increase can be due to older adults being more likely to experience risk factors such as the death of a loved one, a chronic illness, impaired mobility, and retirement (Aartsen and Jylhä, 2011; Cohen-Mansfield et al., 2016; Pinquart and Sorensen, 2001).

Longitudinal research suggests that loneliness may be associated with posttraumatic stress disorder (PTSD) symptomatology (e.g. van der Velden et al., 2018, 2019). However, longitudinal research among these constructs is relatively scarce, with very little research examining this longitudinal relationship among older adults. It is valuable to assess the longitudinal relationship between loneliness and PTSD among older adults because the trajectory of these constructs may be quite different in this cohort of the population. While loneliness often increases in frequency among older adults, numerous epidemiological studies have found that the incidence of PTSD is lowest among the oldest adults in the population (e.g. Gum et al., 2009). It is possible that this opposing trend

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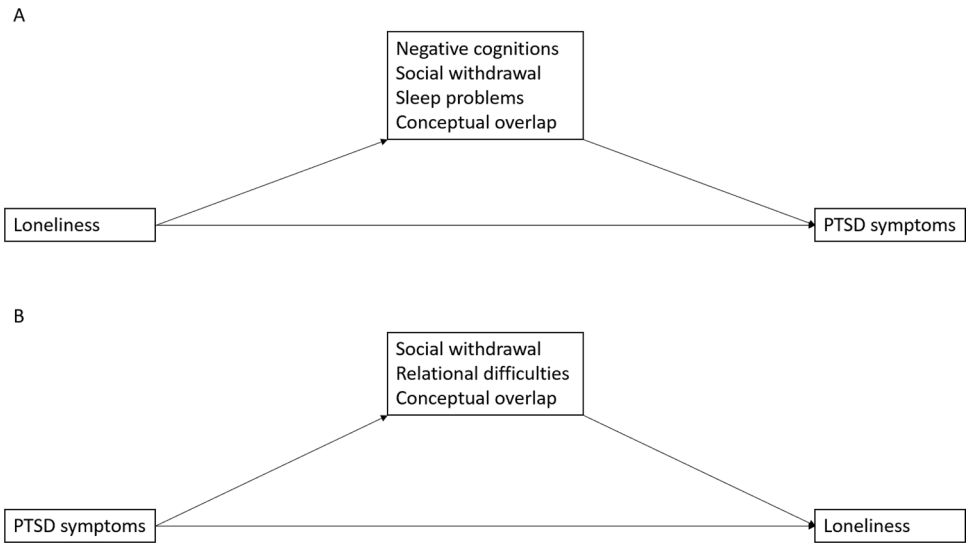

Figure 1. Theoretical pathways demonstrating the bidirectional relationship between loneliness and PTSD symptoms.
Note: Figure illustrates direct and indirect theoretical pathways explaining the causal and possibly bidirectional relationship between loneliness and PTSD symptoms.

(i.e. PTSD symptoms tend to decline in later life, whereas loneliness tends to increase in later life) may impact the temporal association between these constructs, for example, the effect may not persist into later life. Therefore, it is worthwhile to examine the relationship between PTSD and loneliness among older adults.

Loneliness can be maintained through negative cognitive biases such as hypervigilance for social threats (Hawkley and Cacioppo, 2010). A similar psychological disposition is found among individuals suffering from PTSD where a persistent sense of threat occurs despite the lack of a corresponding environmental stimulus (Williamson et al., 2015). Moreover, loneliness is associated with numerous other experiences that are common among trauma exposed persons including re-experiencing/intrusion symptoms (Dagan and Yager, 2019), avoidance symptoms (DePrince et al., 2011), negative evaluations of the world (Cacioppo and Hawkley, 2009), and poor sleep quality (Matthews et al., 2017; McHugh and Lawlor, 2013). Loneliness may also be associated with symptoms such as feelings of alienation, detachment, and estrangement from others (DePrince et al., 2011); however, it is important to note that this association may reflect a conceptual overlap between these constructs.

Longitudinal research in the general population has shown that loneliness does not predict PTSD symptoms among those who have experienced a recent traumatic event (i.e., within the last two months), but it does predict PTSD symptoms among individuals who have experienced a trauma in the more distant past (i.e. in the last 5–12 months) (van der Velden et al., 2019). Given that PTSD symptoms naturally remit for many exposed persons in the first months following their traumatic event (Steinert et al., 2015), these findings suggest that loneliness may interfere with the natural adjustment and recovery process for some trauma-exposed persons. To our knowledge, there is only one study that has examined the relationship between loneliness and PTSD in an older adult sample. In this study, O'Connor (2010) found that social and emotional loneliness measured two months after the death of a spouse were associated with PTSD symptoms 18 months post-bereavement. Although, for most, psychiatric distress following bereavement generally remits over time as individuals adapt to the loss of a loved one (Arizmendi and O'Connor, 2015), it can result in trauma/stressor related conditions such as PTSD, persistent complex bereavement disorder (American Psychiatric Association [APA], 2013), or prolonged grief disorder (World Health Organization [WHO], 2018), most notably when the death of a loved one is sudden or unexpected (Arizmendi and O'Connor, 2015; O'Connor, 2010). Similar to the findings of van der Velden and colleagues (2019), it is possible that loneliness may be a marker of a more complicated bereavement process, whereby intense feelings of loneliness may interfere with the natural recovery process following bereavement.

While there is evidence that loneliness predicts future PTSD symptoms, it is also plausible that PTSD symptoms could predict future feelings of loneliness. For example, social withdrawal and relational difficulties are common experiences among people suffering from PTSD (Solomon and Dekel, 2008; Solomon et al., 2015; Thompson et al., 2018), and it is possible that these behaviours might result in feelings of loneliness. Thus, the association between loneliness and PTSD over time may be reciprocal (see Figure 1 for an illustration of the theoretical pathways explaining the longitudinal relationship between loneliness and PTSD symptoms).

Although symptoms of PTSD are chronic and stable for some individuals; they have been found to fluctuate over time for others in later life (Chopra et al., 2014). Symptoms of PTSD have also been found to re-emerge in later life, possibly due to age-related normative events such as retirement, bereavements, and worsening physical health (Pless Kaiser et al., 2019). For example, veterans who begin to suffer from impaired mobility may re-experience the sense of vulnerability they felt when injured in combat (Pless Kaiser et al., 2019). However, the cause of these fluctuations in later life is not clear. Given the importance of loneliness in later life, and its association with PTSD symptomatology, it may of clinical benefit to examine the longitudinal association between these constructs. As such, determining whether there is a longitudinal association may aid clinicians and researchers in identifying possible variables that precede/predict these fluctuations in PTSD symptoms in later life.

There is limited research examining the longitudinal associations between PTSD and loneliness. Additionally, there is very limited research regarding this relationship among older adults which appears to be a critical period for the experience of loneliness. In this study, we examined the relationship between emotional and social loneliness and posttraumatic stress symptoms across two time points within a sample of older adults. We hypothesised that changes in social and emotional loneliness would be associated with changes in posttraumatic stress symptoms over time.

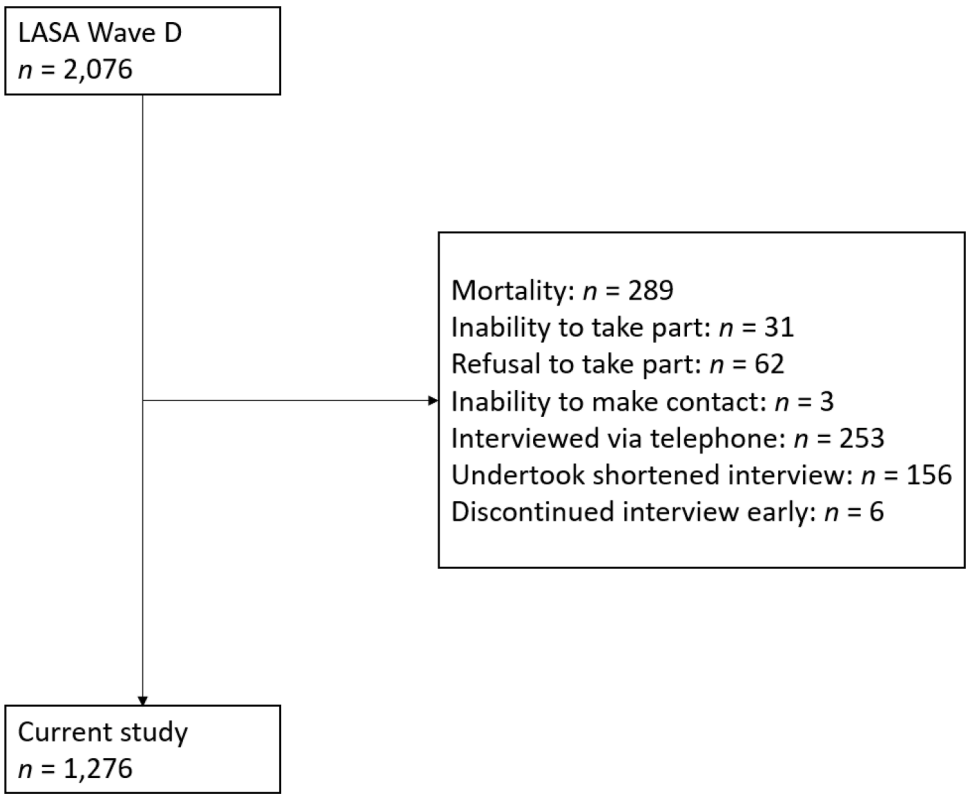

Figure 2. Flowchart presenting breakdown of participants included in the current study.

2. Methods

2.1. Design, Participants and Recruitment Strategy

Participants were drawn from two waves of the Longitudinal Aging Study Amsterdam (LASA). This is an ongoing prospective study that began in 1992/1993, with data being collected approximately every three years. Random samples, stratified for age and sex, of older adults (between the ages of 55-85) were recruited from population registers in nine municipalities across three regions of the Netherlands, with an oversampling of the older-old (aged 75 years and above) and older men to ensure that there were sufficient numbers of older participants after years of follow-up. Participants were interviewed either in their homes by trained persons or took part in a brief interview by telephone instead of the main, in-person, interview. Protocols of the LASA study were approved by the Ethical Review Board of Vrije Universiteit (VU) Medical Center, Amsterdam and all respondents provided informed consent according to prevailing law in the Netherlands. Approval for secondary analysis was granted by the ethical review board of the first author's affiliated institution. Further information on the LASA project is detailed elsewhere (Huisman et al., 2011).

The current sample consisted of data drawn from participants who took part in 'Wave D' ($n = 2,076$; collected in 1998/1999) and 'Wave E' ($n = 1,691$; collected in 2001/2002), henceforth referred to as Time 1 and Time 2, respectively (Figure 2 presents reasons for attrition between waves). These two waves were selected as they were the only assessment periods to include a measure of posttraumatic stress symptoms. Moreover, a number of measures, including posttraumatic stress symptoms, were only assessed during the full main interview. Therefore, as part of the eligibility criteria for the current study, only participants who completed the main interview at both waves ($n = 1,276$) were included in the current sample (see Figure 2). The sample included an almost similar proportion of females (54%, $n = 689$) and males (46%, $n = 587$), and the average age was 72.24 years ($SD = 7.34$), with all adults aged 60 years and older (see Supplementary Table 1 for other sample characteristics).

Differences on the key study variables between responders and non-responders were compared using data from Time 1. Differences were examined across study variables including sex, age, urbanity, education, posttraumatic stress symptoms, and emotional and social loneliness. As part of the eligibility criteria for the current study, we included only those participants who completed the main interview at both waves. Therefore, responders were defined as those who took part in the full main interview at both waves. As such, we were able to examine differences on key study variables such as posttraumatic stress symptoms and loneliness as non-responders who participated in Time 1, but who did not take part in the full main interview at both waves, provided such information.

Compared to non-responders, responders (at Time 1) were more likely to be younger ($t[2,074] = 18.47$, $p < .001$, $d = 0.83$), living in an urban area ($Z = 2.70$, $p = .007$, $r = .06$), have higher education ($Z = -5.57$, $p < .001$, $r = -.12$), lower posttraumatic stress symptoms ($t[1,687] = 2.65$, $p = .008$, $d = 0.15$) lower emotional loneliness ($Z = 5.96$, $p < .001$, $r = .14$), and lower social loneliness ($Z = 2.60$, $p = .009$, $r = .06$). There were no sex differences between responders and non-responders (χ^2 [1, $n = 2,076$] = 2.62, $p = .106$, OR = 0.86 [95% CI 0.72, 1.03]). Although the effect sizes regarding the responders, compared to the non-responders, were generally very small-to-small, there was a large difference between the age of responders compared to non-responders. This difference is not surprising given that mortality was the primary reason for attrition between waves (see Figure 2). This was expected during the initial data collection of the LASA, as adults in the older-old age category were oversampled to account for this attrition.

2.2. Measures

2.2.1. Posttraumatic stress symptoms

Posttraumatic stress symptoms were measured using the Self-Rating Inventory for Posttraumatic Stress Disorder (SRIP; Hovens et al., 1994). The SRIP is a 22-item Dutch questionnaire designed to assess the presence (within the last four weeks) of the 17 PTSD symptoms that were outlined in the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-IV*; APA, 1994). As such, these items can be clustered into three groups representing 'Re-experiencing' symptoms (six items; e.g. "I had the feeling that past events were happening again"), 'Avoidance and Numbing' symptoms (nine items; e.g. "I tried to avoid situations that would recall past events"), and 'Hyperarousal' symptoms (seven items; e.g. "I was easily frightened"). All items are rated on a four-point Likert-scale ('not at all' = 1, 'extremely' = 4). Higher scores indicate greater posttraumatic stress symptoms with total scores ranging from 22–88. These symptoms are in reference to unspecified traumatic events (referred to simply as "past events"). The use of non-specific traumatic events may be beneficial among older samples that are less likely to disclose potentially sensitive information due to fears of stigma (Thomas et al., 2016). Previous research utilising data drawn from the LASA project found support for the reliability and validity of this instrument among community-dwelling older adults (Van Zelst et al., 2003). Moreover, the SRIP has demonstrated good concurrent validity with PTSD measures such as the Clinician Administered PTSD Scale (CAPS) (Hovens et al., 1994; Kok et al., 2013). The internal consistency (Cronbach's alpha) of the SRIP scale in the current sample at Time 1 ($\alpha = .87$) and Time 2 ($\alpha = .86$) were satisfactory. In order to reduce model complexity, the items representing each symptom cluster were parcelled to create three variables (Re-experiencing, Avoidance and Numbing, and Hyperarousal) that loaded onto a single unidimensional posttraumatic stress symptoms latent variable.

2.2.2. Loneliness

The 11-item De Jong Gierveld Loneliness Scale (De Jong-Gierveld and Kamphuis, 1985; De Jong-Gierveld and van Tilburg, 2006) was used to assess social and emotional loneliness. This is a multidimensional scale consisting of five positively phrased items measuring social loneliness (e.g. "I can call on my friends whenever I need them") and six negatively phrased items measuring emotional loneliness (e.g. "I often feel rejected"), assessed on a three-point Likert scale ('no' = 1, 'more-or-less' = 2, 'yes' = 3). The items are then dichotomised (0 = 'absence of loneliness item', 1 = 'presence of loneliness item') whereby 'more-or-less' is merged with 'no' for the positive items, and 'yes' for the negative items (i.e. responding 'more-or-less' indicates loneliness), and the scores on positively phrased items are reversed so that higher scores are indicative of greater levels of loneliness (De Jong-Gierveld and Kamphuis, 1985). Possible scores on the social loneliness dimension range from 0-5, and emotional loneliness scores range from 0–6. Prior research has found support for the reliability and validity of this measure (van Tilburg and De Leeuw, 1991). Within the current sample, the internal consistencies were satisfactory for the full loneliness scale at both Time 1 ($\alpha = .81$) and Time 2 ($\alpha = .82$), the social loneliness dimension at Time 1 ($\alpha = .73$) and Time 2 ($\alpha = .75$), and the emotional loneliness dimension at Time 1 ($\alpha = .81$) and Time 2 ($\alpha = .80$).

2.2.3. Covariates

A number of covariates were assessed at Time 1 including age (using date of birth), sex (official status as registered with the participant's respective municipal registry office; coded as 0 = male, 1 = female), urbanity, partner status (0 = 'no partner', 1 = 'partner cohabiting/non-cohabiting'), and education. Urbanity was measured as the mean number of addresses per squared kilometre within a circle with a radius of one kilometre, using the participant's postal code for reference (categorised into five categories ranging from < 500 to ≥ 2500). Education data was collected using nine categories ranging from "elementary not completed" to "university education". In addition to partner status, we included personal network size (the number of people that the participant is in contact with regularly and who they also consider to be important to them), as a potential confounding variable to control for the effects of social connectedness/isolation. To ensure that the results observed reflect the covariation between posttraumatic stress symptoms and loneliness, and are not the result of recent stressful events being a shared risk factor of both posttraumatic stress symptoms and loneliness, we included a count of recent negative life events as a covariate. These recent negative life events (categorised as 0, 1, 2, 3+ recent negative life events) occurred within the last three years (this included the death of a family member, illness of a partner/relative, victim of a crime, serious conflict with others, and serious financial troubles). These covariates were selected to control for any confounding effect (see VanderWeele, 2019) that they may have on the relationships among the primary variables of interest (i.e. associated with PTSD symptoms, emotional loneliness and/or social loneliness) (e.g. Drennan et al., 2008; Gum et al., 2009; Hyland et al., 2019; McHugh Power et al., 2019; Tolin and Foa, 2006; Tomaka et al., 2006; Ventimiglia and Seedat, 2019). We included additional analyses as supplementary information excluding partner status and personal network size, as these variables may arguably be overadjusting the model.

2.3. Analytical Plan

First, zero-order correlations were calculated to determine the bivariate associations among all study variables. Spearman's rho (ρ) was used for bivariate associations involving at least one categorical variable of more than two levels (i.e. urbanity, education, recent negative life events, social loneliness, and emotional loneliness), whereas, Pearson's *r* coefficient was used for the remaining bivariate associations. Moreover, change over time for posttraumatic stress symptoms was measured using a paired samples *t*-test (and Cohen's *d* as a measure of effect size; 0.2 is a small, 0.5 a medium, and 0.8 a large effect); whereas, emotional and social loneliness change over time was assessed using a Wilcoxon signed-rank tests (and *r* as a measure of effect size; .1 is a small, .3 a medium, and .5 a large effect), given the ordinal nature of the data.

Second, in order to examine intraindividual change over time, it is often implicitly assumed, or is most accurate when, the metric(s) being examined is invariant across the different time points (Liu et al., 2017). Therefore, to ensure that individual changes observed over time are a reflection of changes in the level of the construct and not changes in what is being measured, we examined the longitudinal measurement invariance (see Liu et al., 2017; Millsap and Yun-Tein, 2004) of each latent variable (i.e. posttraumatic stress symptoms, and social and emotional loneliness).

Third, to examine intraindividual (changes across time for posttraumatic stress symptoms, social loneliness, and emotional loneliness) and interindividual (changes in social loneliness and emotional loneliness are related to changes in posttraumatic stress symptoms) change over time, we employed a recently developed statistical approach, termed the 'two-wave latent change score' model (2W-LCS; see Henk and Castro-Schilo, 2016). This approach examines relationships between changes in multiple constructs across time. As a preliminary step to examining change-to-change relationships for posttraumatic stress symptoms, social loneliness, and emotional loneliness, it was necessary to first fit univariate LCS models for the individual constructs. This determines whether there were significant mean and variance changes in the respective LCS. Next, we fitted the multivariate 2W-LCS model where the within-person change in posttraumatic stress symptoms (denoted as Δposttraumatic stress symptoms) was regressed onto the within-person change for social loneliness (Δsocial loneliness) and emotional loneliness (Δemotional loneliness). Moreover, the LCSs were regressed onto the exogenous covariates (age, sex, urbanity, partner status, education, personal network size, and recent negative life events). Due to the nonnormality of the posttraumatic stress symptoms

variables, as indicated by significant Mardia's multivariate normality tests (all $p < .001$), the univariate posttraumatic stress symptoms model was estimated using the robust maximum likelihood (MLR) estimator. This estimator is robust to nonnormally distributed data and can correct for such issues of multivariate nonnormality. Whereas, the emotional loneliness and social loneliness models were estimated using the robust weighted least squares estimator (WLSMV) estimator, as this estimator performs best with categorical data (Brown, 2006), with theta parametrisation in order to estimate/constrain unique factor variances over time. Moreover, the multivariate 2W-LCS model was estimated using WLSMV with theta parametrisation.

It is important to note that as the 2W-LCS approach examines the change-to-change relationship of multiple constructs over a single period of time (i.e. across two waves), this precludes any statistical inferences regarding the precise temporal ordering of the relationship (Henk and Castro-Schilo, 2016). In order to ascertain the precise temporal relationship (e.g. changes in loneliness precede changes in posttraumatic stress symptoms), it would be necessary to collect at least three waves of data. That is, in order to determine whether changes in one construct precede changes in another (i.e. change in one construct will cause another construct to change), there would need to be at least two intervals of change (for example, across three waves). Nonetheless, Henk and Castro-Schilo (2016) argue that researchers should not be dissuaded from using two-waves of data and found that the 2W-LCS approach still provides useful information by identifying the initial evidence of longitudinal associations among covarying constructs. As the 2W-LCS model allows for the estimation of both within-person and between-person change, it is possible to successfully examine change-to-change hypotheses (i.e. between-person differences in intra-individual change scores on one construct will predict between-person differences in intraindividual change scores on another construct).

Model fit was assessed using multiple goodness-of-fit indices (Hooper et al., 2008). Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values $\geq .90$ indicate adequate model fit, with stricter criteria of $\geq .95$ to indicate good fit. Additionally, Root Mean Square Error of Approximation (RMSEA) values $\leq .08$ indicate adequate model fit, with stricter criteria of $\leq .06$ as being indicative of good model fit. Analyses were conducted using the lavaan package (Rosseel, 2012) in R 3.6.3 (R Development Core Team, 2020).

3. Results

3.1. Zero-order Correlations and Change Over Time

Supplementary Table 2 displays the zero-order correlations among all observed study variables. Posttraumatic stress symptoms, emotional loneliness, and social loneliness were associated with the majority of study variables. The strongest associations were the autocorrelations between posttraumatic stress symptoms ($r = .66$ $p < .001$), emotional loneliness ($\rho = .64$, $p < .001$), and social loneliness ($\rho = .56$, $p < .001$). Among the observable variables, there was a very small increase in posttraumatic stress symptoms ($t[1,246] = -5.79$, $p < .001$, $d = -0.16$) from Time 1 ($M = 31.68$, $Mdn = 30.00$, $SD = 7.83$) to Time 2 ($M = 31.74$, $Mdn = 31.00$, $SD = 7.83$). Although this increase was statistically significant, it is unlikely to be a substantively meaningful increase given that the effect size was less than 'small'. Similarly, there was a very small increase in emotional loneliness ($Z = -2.73$, $p = .006$, $r = -.05$) from Time 1 ($M = 1.14$, $Mdn = 0.00$, $SD = 1.67$) to Time 2 ($M = 1.23$, $Mdn = 0.00$, $SD = 1.70$), whereas, there was no significant change in social loneliness scores ($Z = -0.18$, $p = .857$, $r = .00$) from Time 1 ($M = 0.97$, $Mdn = 0.00$, $SD = 1.37$) to Time 2 ($M = 0.99$, $Mdn = 0.00$, $SD = 1.39$). The effect sizes were also less than 'small' suggesting that these were not substantively meaningful changes.

3.2. Longitudinal Measurement Invariance

Table 1 presents the fit statistics and nested model comparisons for the unidimensional model of posttraumatic stress symptoms, and the multidimensional model of loneliness (i.e. social and emotional loneliness). Both posttraumatic stress symptoms and loneliness achieved strict invariance (i.e. factor loadings, intercepts/thresholds, and unique factor variances constrained equal across time) as indicated by the non-significant likelihood ratio test (LRT), ΔCFI and ΔTLI $< .010$, and ΔRMSEA $< .015$ (Chen, 2007; Cheung and Rensvold, 2002). Therefore, these constructs could be examined across time using LCS.

3.3. Univariate LCS

Univariate LCS models were specified for posttraumatic stress symptoms, emotional loneliness, and social loneliness. The posttraumatic stress symptoms univariate LCS model provided excellent fit to the data ($\chi^2[12] = 12.17$, $p = .433$; CFI = 1.000; TLI = 1.000; RMSEA = .003 [90% CI .000, .026]). The mean of the posttraumatic stress symptoms LCS was significant ($\mu_{\Delta posttraumatic\ stress\ symptoms} = 0.145$, $p < .001$) indicating that, on average, individuals increased from Time 1 to Time 2, however, there was also significant within-person heterogeneity suggesting that not all participants followed this trajectory, as indicated by the significant variance ($\sigma^2_{\Delta posttraumatic\ stress\ symptoms} = 0.520$, $p < .001$). Similarly, the emotional loneliness univariate LCS model provided excellent fit to the data ($\chi^2[57] = 102.21$, $p < .001$; CFI = .996; TLI = .995; RMSEA = .025 [90% CI .017, .033]). The mean ($\mu_{\Delta emotional\ loneliness} = 0.081$, $p = .046$) and variance ($\sigma^2_{\Delta emotional\ loneliness} = 0.338$, $p < .001$) of the emotional loneliness LCS was also significant, indicating that scores increased over time. The social loneliness univariate LCS model also provided excellent fit to the data ($\chi^2[37] = 45.05$, $p = .171$; CFI = .999; TLI = .998; RMSEA = .013 [90% CI .000, .025]). The mean of the social loneliness LCS was non-significant ($\mu_{\Delta social\ loneliness} = -0.012$, $p = .806$) but the variance was significant ($\sigma^2_{\Delta social\ loneliness} = 0.383$, $p < .001$) suggesting that although there was no general trend regarding increases/decreases in social loneliness, there was significant within-person heterogeneity (Henk and Castro-Schilo, 2016).

3.4. Multivariate 2W-LCS

The 2W-LCS model provided adequate fit to the data ($\chi^2[528] = 1713.75$, $p < .001$; CFI = .909; TLI = .935; RMSEA = .043 [90% CI .040, .045]), and explained 17% of the variance relative to Δposttraumatic stress symptoms, 32% relative to Δemotional loneliness, and 29% relative to Δsocial loneliness. While controlling for exogenous covariates, both Δemotional loneliness and Δsocial loneliness were associated with small changes in Δposttraumatic stress symptoms. Moreover, older age, sex (being female), and urbanity were associated with Δposttraumatic stress symptoms. Older age, partner status (no partner), decreased personal network size, and recent negative life events were associated with increased Δemotional loneliness. Older age, sex (being male), urbanity, and decreased personal network size were associated with increased Δsocial loneliness (see Table 2 for all parameter estimates, and Figure 3 for structural model illustrating the relationship among all latent variables). Additionally, see Supplementary Table 3 for parameter estimates and model fit excluding partner status and personal network size variables, as controlling for these variables may arguably lead to overadjustment.

3.5. Post-hoc Power Analyses

Post-hoc power analyses were conducted using the semPower package (Moshagen and Erdfelder, 2016) in R. Using an RMSEA criteria $\leq .06$ as indicating acceptable model fit and alpha level of .05 (see Moshagen and Erdfelder, 2016), all models were found to be sufficiently powered ($1 - \beta$ [Type II error rate] values of greater than 0.97, indicating

Table 1
Longitudinal measurement invariance tests of posttraumatic stress symptoms and loneliness (social and emotional) models.

	χ^2	df	CFI	TLI	RMSEA (90% CI)	ΔCFI	ΔTLI	ΔRMSEA	LRT $\Delta\chi^2$ (p)[a]
Posttraumatic stress symptoms									
Configural	3.130	5	1.000	1.000	.000 (.000-.024)	–	–	–	–
Weak[a]	4.384	7	1.000	1.000	.000 (.000-.020)	.000	.000	.000	1.253 (.534)
Strong[b]	5.026	9	1.000	1.000	.000 (.000-.022)	.000	.000	.000	0.452 (.798)
Strictc[c]	12.165	12	1.000	1.000	.003 (.000-.026)	.000	.000	.003	6.755 (.082)
Loneliness									
Configural[d]	709.210***	192	.965	.958	.046 (.042-.050)	–	–	–	–
Weak[e]	709.007***	201	.966	.961	.045 (.041-.048)	.001	.003	.001	3.931 (.916)
Strict[f]	673.667***	231	.969	.966	.042 (.038-.045)	.003	.005	.003	11.285 (.257)

Note: Loneliness = multidimensional model consisting of social and emotional loneliness; χ^2 = Chi-square Goodness of Fit statistic; df = degrees of freedom; CFI = Comparative Fit Index; TLI = Tucker Lewis Index; RMSEA (90% CI) = Root-Mean-Square Error of Approximation with 90% confidence intervals; Δ = change/difference in value; LRT = likelihood ratio test; [a] = LRT $\Delta\chi^2$ is based on the standard χ^2, whereas model fit is based on the robust χ^2; [a] = factor loadings constrained equal; [b] = factor loadings and intercepts constrained equal; [c] = factor loadings, intercepts, and unique factor variances constrained equal; [d] = thresholds constrained equal with dichotomous indicators, for model identification; [e] = factor loadings and thresholds constrained equal; [f] = factor loadings, thresholds, and unique factor variances constrained equal. Statistical significance: *$p < .05$; **$p < .01$; ***$p < .001$.

Table 2
Standardised and unstandardised parameter estimates for the 2W-LCS model examining change-to-change relationship between posttraumatic stress symptoms, and emotional and social loneliness.

	Δ Posttraumatic stress symptoms		Δ Emotional loneliness		Δ Social loneliness	
	B (SE)	β (SE)	B (SE)	β (SE)	B (SE)	β (SE)
Latent change scores						
Δ Emotional loneliness	.16* (.08)	.16 (.08)	–	–	–	–
Δ Social loneliness	.17* (.08)	.15 (.07)	–	–	–	–
Covariates						
Age	.02*** (.01)	.17 (.05)	.03*** (.01)	.23 (.05)	.02*** (.01)	.18 (.05)
Sex[a]	.18* (.07)	.11 (.04)	.15 (.08)	.09 (.05)	-.26** (.08)	-.17 (.05)
Partner status[b]	.07 (.08)	.04 (.05)	-.53*** (.09)	-.31 (.05)	-.16 (.09)	-.10 (.05)
Urbanity	.05* (.02)	.08 (.04)	.03 (.03)	.05 (.05)	.09** (.03)	.16 (.05)
Education	-.03 (.02)	-.08 (.04)	-.02 (.02)	-.05 (.05)	.00 (.02)	.00 (.05)
Personal network size	.00 (.01)	-.04 (.06)	-.01** (.01)	-.16 (.05)	-.03*** (.01)	-.41 (.05)
Recent NLE	.07 (.04)	.07 (.04)	.15** (.04)	.16 (.04)	.01 (.04)	.01 (.05)

Note: 2W-LCS = two-wave latent change score; Recent NLE = recent negative life events; B = unstandardised estimates; β = standardised estimates; SE = standard error
[a] = sex coded as 0 = male, 1 = female
[b] = partner status coded as 0 = no partner, 1 = partner. Statistical significance: *$p < .05$; **$p < .01$; ***$p < .001$.

high power). Missing data for the multivariate 2W-LCS were minimal (3.0% of all cases had any missing data) and were handled using the default (lavaan) listwise deletion.

4. Discussion

This study was conducted to address a gap in the literature regarding the longitudinal relationship between loneliness and PTSD symptoms by examining the change-to-change relationship between social and emotional loneliness and posttraumatic stress symptoms among a sample of older adults. In line with previous research (Solomon et al., 2015), we found cross-sectional associations between social and emotional loneliness and posttraumatic stress symptoms at both time-points. Furthermore, consistent with our hypothesis and prior findings (van der Velden et al., 2018, 2019), we found evidence of a longitudinal association with changes in emotional loneliness and social loneliness relating to changes in posttraumatic stress symptoms. Given the limitations of using only two waves of data, we could not directly infer the temporal ordering of these constructs. As such, it is possible that this longitudinal association is bidirectional.

These findings suggest that a lack or absence of intimate relationships and close attachments (i.e. emotional loneliness), and the desire for a sense of belonging and companionship within a wider network (i.e. social loneliness) are associated with changes in posttraumatic stress symptoms over time. Previous research (DePrince et al., 2011) has noted that trauma exposed individuals can feel alienated from others in society and these feeling may be associated with a longing for close attachments and a desire to belong within a wider network. These feelings of loneliness may ultimately lead to posttraumatic stress symptoms via a number of pathways. For example, loneliness may lead to the development of negative cognitions (Cacioppo and Hawkley, 2009), which can predict future PTSD symptoms and impact PTSD treatment (Brown et al., 2019). Similarly, loneliness can lead to sleep problems (Matthews et al., 2017; McHugh and Lawlor, 2013), which can result in increased PTSD symptoms (Dagan and Yager, 2019). Loneliness can also lead to social withdrawal (Hawkley and Cacioppo, 2010), which is a form of avoidant coping that can maintain PTSD symptoms (Thompson et al., 2018). According to the loneliness loop (Hawkley and Cacioppo, 2010), as loneliness can lead to social withdrawal, this in turn contributes to a greater sense of loneliness. As feelings of loneliness can be reciprocal/self-reinforcing in nature (McHugh Power et al., 2019), loneliness may serve to maintain PTSD symptoms over time. Moreover, as PTSD symptoms can fluctuate over time in later life (Chopra et al., 2014), it is possible that changes in loneliness may be an important precursor to these fluctuations in PTSD symptoms.

In this study, the changes in posttraumatic stress symptoms, emotional loneliness, and social loneliness occurred over the one time period. Therefore, it is possible that this relationship is bidirectional (i.e., that posttraumatic stress symptoms also leads to changes in emotional loneliness and social loneliness). For example, PTSD symptoms such as negative cognitive biases and a sense of threat are similar to those expressed by lonely individuals, such as an implicit hypervigilance for social threat, and can lead to social withdrawal, thereby leading to a sense of loneliness. Moreover, PTSD avoidance symptoms may also lead an individual distancing themselves emotionally from others within their close network (Solomon and Dekel, 2008), which may lead to

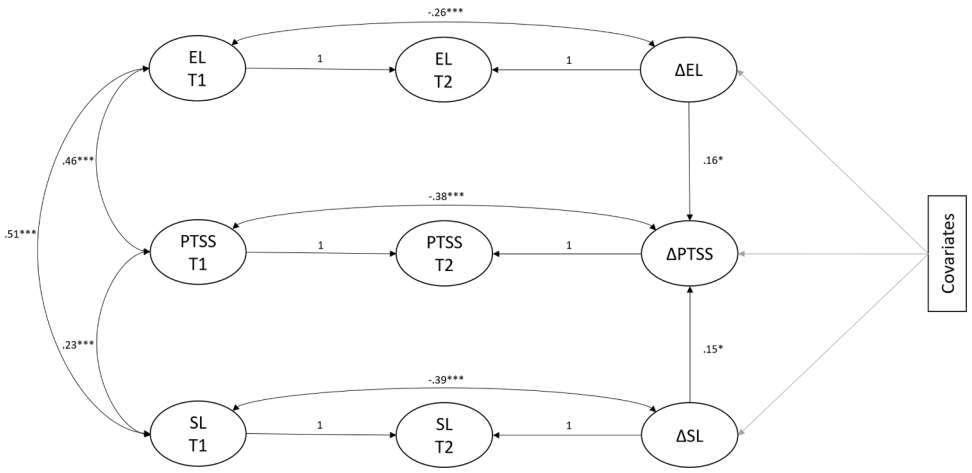

Figure 3. Structural model illustrating the change-to-change relationship between posttraumatic stress symptoms, and emotional and social loneliness.
Note: Individual exogenous covariate pathways are omitted for visual clarity. T1 = Time 1; T2 = Time 2; PTSS = posttraumatic stress symptoms; EL = emotional loneliness; SL = social loneliness. Statistical significance: $*p < .05$; $**p < .01$; $***p < .001$.

increased feelings of loneliness. Similarly, Glover (1988) noted a PTSD syndrome characterised by feelings and attitudes of mistrust and alienation among Vietnam veterans. These individuals expressed difficulties feeling intimacy with friends or family members and would often avoid/undermine the possibility of becoming involved in a trusting relationship. It is possible that these feelings of mistrust and inability to engage in a trusting, close relationship may lead to feelings of emotional loneliness, whereas feelings of alienation may lead to social loneliness. However, it is uncertain whether these veterans were less able to build trusting relationships prior to the Vietnam War. These points are speculative, given the limited data available on the longitudinal association between loneliness and PTSD, but offer possible avenues for future research. Moreover, it is possible that different types/severity of traumatic events may play a role in determining the association between PTSD and loneliness in older age, such as sudden or unexpected bereavement compared to bereavement that is not sudden or unexpected. As such, future research should aim to delineate the pathways from PTSD to loneliness, using longitudinal data and measures of trauma type and severity.

Changes in posttraumatic stress symptoms were associated with older age, female sex, and urbanity. Solomon et al. (2012) noted that an increase in PTSD symptoms in later life may be due to the aging process. For example, retired individuals have more opportunity to reflect on their life and may, therefore, recall early traumatic memories resulting in an increase of PTSD symptoms. Additionally, there is considerable evidence that females are at least twice as likely as males to suffer from PTSD, and those living in cities are also more likely to suffer from PTSD (Tolin and Foa, 2006; Ventimiglia and Seedat, 2019). Thus, these well-established predictors of PTSD appear to hold into older age.

Changes in emotional loneliness were associated with older age, recent negative life events, decreased personal network size, and partner status; whereas changes in social loneliness were associated with older age, being male, urbanity, and decreased personal network size. These findings are generally in line with the wider loneliness literature (Drennan et al., 2008; Luhmann and Hawkley, 2016; Tomaka et al., 2006). Previous research has found an association between emotional loneliness and trauma exposure (Hyland et al., 2019). Moreover, this finding coincides with previous research suggesting that trauma exposure may lead to feelings of mistrust or avoidance which may impede the development of close connections (Glover, 1988; Solomon and Dekel, 2008).

There are several limitations that should be acknowledged. First, the present study used a sample of older Dutch adults, therefore these findings may not be generalisable to older adults in other nations, or to in-patient clinical settings. Second, the current sample used a broad age range to examine the relationship between posttraumatic stress symptoms and loneliness in older adults. Future research should aim to use a narrower age range to determine whether these effects are observed across all age groups in later life. Third, it is important to note when interpreting differences between social and emotional loneliness that the multidimensional structure of the loneliness measure used (De Jong Gierveld Loneliness Scale; De Jong-Gierveld and Kamphuis, 1985) has been criticised to reflect, at least in part, a method effect associated with the wording of the positively phrased items, compared to the negatively phrased items (Penning et al., 2014). Fourth, as the measure of PTSD used did not ask participants to disclose the specific index trauma related to their PTSD symptoms, it was not possible to determine the specific types of traumatic events that may be associated with changes in PTSD and loneliness over time. Future research should aim to include a measure of traumatic events experienced. Moreover, it may be worthwhile to assess the length of time since the trauma has occurred and the impact that this may have on the association between PTSD and loneliness. Fifth, it should be noted that, as the data used in the present study was collected approximately 20 years ago, the measure of PTSD used is not reflective of most contemporary models of PTSD. As such, it will be important to replicate this study using measures designed to capture more contemporary models of PTSD such as those outlined in the eleventh version of the *International Classification of Diseases* (*ICD-11*; WHO, 2018) or *DSM-5* (APA, 2013), as both of these models have recently been found to adequately represent PTSD in later life (Fox et al., 2020). However, given the substantial overlap between the *DSM-IV* and *DSM-5* models of PTSD (Carmassi et al., 2013; Rosellini et al., 2015), these findings still add a substantive contribution to the PTSD literature. Nevertheless, there are important differences to acknowledge across these classifications of PTSD, such as the *DSM-5* model consisting of 20 symptoms across four symptom clusters, compared to the *DSM-IV* model consisting of 17 symptoms across three symptom clusters. Therefore, the use of the *DSM-IV* model of PTSD does not fully capture the broader symptom criteria and heterogeneous symptom profiles associated with the *DSM-5* classification (Galatzer-Levy and Bryant, 2013; Weathers, 2017). This difference in symptom criteria can lead to a discordance in PTSD diagnosis (Crespo and Gómez, 2016; Forbes et al., 2011; Hoge et al., 2014; Schnyder et al., 2015; Weathers, 2017). As such, to mitigate the impact of this limitation and avoid diagnostic misclassifications, we only used a continuous measure of PTSD symptomatology. Sixth, we found that there were significant differences between responders and non-responders in several of the study variables. However, we accounted for missing data using all information available, wherever possible,

to minimise the impact of this limitation. Seventh, as the changes in the constructs measured only occurred across two time points, it was not possible to determine the precise temporal ordering between post-traumatic stress symptoms and loneliness. Future research should aim to address this limitation using more waves of data.

Loneliness is known to play a key role in numerous psychopathologies and our findings provide further evidence that this extends to PTSD. We have demonstrated a longitudinal association between social and emotional loneliness and posttraumatic stress symptoms among older adults. Clinicians should be aware of this association when treating older adults who present with symptoms of PTSD, as targeting feelings of loneliness may be an effective means to ameliorating these psychiatric symptoms. For example, if loneliness interacts with PTSD symptoms via reciprocal pathways, then treating loneliness among older adults may be effective in abating symptoms of PTSD. Moreover, treating loneliness among older adults who have experienced a traumatic event may reduce the likelihood of developing future symptoms of PTSD by preventing behaviours, such as social withdrawal, that may impede recovery following trauma exposure. Additionally, these findings may help researchers to better understand the factors that impact the course of PTSD among older adults. In summary, loneliness is likely to be a clinically meaningful construct among trauma-exposed persons and those experiencing PTSD symptoms in later life.

Declaration of Competing Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Authorship contribution statement

Robert Fox: Conceptualisation, methodology, acquisition of data, statistical analyses/interpretation of data, contributed to the writing, revising, and editing of the manuscript. **Joanna McHugh Power:** Project administration, conceptualisation, methodology, supervision, statistical analyses/interpretation of data, contributed to the writing, revising, and editing of the manuscript. **Andrew N. Coogan:** Project administration, conceptualisation, methodology, supervision, interpretation of data, contributed to the writing, revising, and editing of the manuscript. **Aartjan T.F. Beekman:** Methodology, interpretation of data, contributed to the writing, revising, and editing of the manuscript. **Theo G. van Tilburg:** Methodology, interpretation of data, contributed to the writing, revising, and editing of the manuscript. **Philip Hyland:** Project administration, conceptualisation, methodology, supervision, statistical analyses/interpretation of data, contributed to the writing, revising, and editing of the manuscript. All authors contributed to and have approved the final manuscript.

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Data accessibility statement

Data from the Longitudinal Aging Study Amsterdam (LASA) are available for use for specific research questions, provided that an agreement is made up. Research proposals should be submitted to the LASA Steering Group, using a standard analysis proposal form that can be obtained from the LASA website: www.lasa-vu.nl. Files with data published in this publication are freely available for replication purposes and can be obtained using the same analysis proposal form. The LASA Steering Group will review all requests for data to ensure that proposals for the use of LASA data do not violate privacy regulations and are in keeping with informed consent that is provided by all LASA participants.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2021.113846.

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