



## Original Contribution

# On the Reciprocal Association Between Loneliness and Subjective Well-being

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Loneliness has been shown to longitudinally predict subjective well-being. The authors used data from a longitudinal population-based study (2002–2006) of non-Hispanic white, African-American, and nonblack Latino-American persons born between 1935 and 1952 and living in Cook County, Illinois. They applied marginal structural models for time-varying exposures to examine the magnitude and persistence of the effects of loneliness on subjective well-being and of subjective well-being on loneliness. Their results indicate that, if interventions on loneliness were made 1 and 2 years prior to assessing final subjective well-being, then only the intervention 1 year prior would have an effect (standardized effect =  $-0.29$ ). In contrast, increases in subjective well-being 1 year prior (standardized effect =  $-0.26$ ) and 2 years prior (standardized effect =  $-0.13$ ) to assessing final loneliness would both have an effect on an individual's final loneliness. These effects persist even after control is made for depressive symptoms, social support, and psychiatric conditions and medications as time-varying confounders. Results from this study indicate an asymmetrical and persistent feedback of fairly substantial magnitude between loneliness and subjective well-being. Mechanisms responsible for the asymmetry are discussed. Developing interventions for loneliness and subjective well-being could have substantial psychological and health benefits.

causal models; loneliness; marginal structural models; subjective well-being

Abbreviations: CES-D, Center for Epidemiologic Studies-Depression; CHASRS, Chicago Health, Aging, and Social Relations Study; CI, confidence interval; R-UCLA, revised version of the UCLA (University of California, Los Angeles) Loneliness Scale.

There is now a substantial literature suggesting that loneliness has powerful effects on both physical (1–6) and mental (7–13) health. These associations persist after control is made for objective social isolation or social support (3, 14). Loneliness has been shown to have a moderately strong association with subjective well-being, both cross-sectionally and longitudinally—an association that persists after controlling for baseline subjective well-being and for age, gender, ethnicity, income, and even marital status (15). Subjective well-being is likewise itself related to a variety of health outcomes (15).

The associations between loneliness and subjective well-being are complicated in that there may be potential feedback present between these variables. Loneliness is synonymous with perceived social isolation and is defined by

the distress that accompanies a perceived discrepancy between one's desired and actual social relationship quantity and especially quality. Subjective well-being refers to people's emotional and cognitive evaluations of their lives. Loneliness may lead to lower subjective well-being (15). Conversely, individuals with lower subjective well-being may socially withdraw, leading to higher levels of loneliness, and individuals with a perception of high levels of subjective well-being may act more positively towards others prompting a positive response, closer social ties, and a yet greater sense of subjective well-being (16, 17). Consistent with both perspectives, longitudinal analyses have suggested a reciprocal influence between loneliness and subjective well-being (15).

Study of the association between loneliness and subjective well-being is complicated by the relation of both these

constructs with depression and social support, however. Psychometric studies designed to determine the association among loneliness, depressive symptoms, and social support have found them to be distinct constructs statistically (7, 13, 18–21) and functionally (14, 22–24). Loneliness, for instance, predicts subsequent depression longitudinally, even after control is made for initial depression levels (7, 14, 25–28). Subjective well-being, social support, and depression are likewise closely related but are conceptually and empirically distinct (15). In addition, although there is a clear inverse association between depression and subjective well-being (29, 30), recent empirical work (31) indicates that subjective well-being has relatively poor predictive ability for diagnosing clinical depression, with many clinically depressed individuals having considerably higher levels of subjective well-being than anticipated (32). Nevertheless, in examining the effects of subjective well-being on loneliness and of loneliness on subjective well-being, it is important that appropriate control be made for depressive symptoms and social support so as to avoid conflation of these related constructs with either loneliness or subjective well-being.

Levels of loneliness, subjective well-being, social support, and depressive symptoms vary over time. To tease apart the effects of one of these on another, methods need to be used that can handle feedback and time-varying confounding. We use causal models for time-varying exposures, namely, marginal structural models (33), to study the reciprocal associations between loneliness and subjective well-being and the extent to which the effect of one on the other persists over time.

That loneliness and subjective well-being may each affect the other has been noted before. For example, in a review paper, Diener and Ryan (34) suggested and provided evidence that subjective well-being and sociality (not loneliness *per se*) are bidirectionally associated. Much of the relevant work, however, has been cross-sectional. That loneliness is associated with and predicts subsequent well-being has been established (35–37), but the reverse direction has been less well examined. What the current analyses furthermore contribute is evidence concerning the relative persistence of these effects. To our knowledge, this is the first study that has applied marginal structural models to examine feedback between loneliness and subjective well-being.

Questions about the effects of time-varying exposures cannot be addressed with simple linear regression techniques when confounders are also time varying (33, 38). Such questions could potentially be addressed through a structural equation model. However, structural equation models require a much larger number of distributional and functional form assumptions than the approach described here (38, 39). Moreover, a structural equation model is subject to other more subtle confounding biases that are partially circumvented by the marginal structural model approach (40, 41).

We therefore applied marginal structural models to longitudinal data from a population-based longitudinal study to determine the nature of the influence between loneliness and subjective well-being for a representative sample of middle-aged and older adults. These models allow for

**Table 1.** The Five Items<sup>a</sup> on the Satisfaction with Life Scale

- |   |
|---|
| 1. In most ways my life is close to my ideal.                   |
| 2. The conditions of my life are excellent.                     |
| 3. I am satisfied with my life.                                 |
| 4. So far, I have gotten the important things I want in life.   |
| 5. If I could live my life over, I would change almost nothing. |

<sup>a</sup> Each item was rated on a scale from 1 to 7.

control for time-varying confounding by depressive symptoms and social support, and they also allow one to assess how subjective well-being depends on not simply loneliness at a single point in time but an entire history of loneliness and likewise how loneliness itself might depend on the entire prior history of subjective well-being.

## MATERIALS AND METHODS

### Sample and design

Data were obtained from the Chicago Health, Aging, and Social Relations Study (CHASRS). CHASRS is a population-based study of individuals living in Cook County, Illinois, aged 50–67 years at baseline and then followed up once per year for 4 additional years. The study included non-Hispanic Caucasian, African-American, and Latino-American individuals; a multistage probability design in which African Americans and Latino Americans were oversampled was used. A sample of households was first selected that was estimated to have high probability of containing at least 1 adult aged 50–65 years; then sampled households were screened by telephone for an age-eligible person, selecting the individual with the most recent birthday when households contained more than 1 age-eligible person. A quota sampling strategy was used to achieve an approximately equal distribution of respondents across the 6 gender-by-race/ethnicity categories. The response rate was 45% with 229 individuals at baseline, and comparisons of data from CHASRS and the nationally representative Health and Retirement Study confirmed that participants in CHASRS were representative of US citizens living in urban settings.

Participants came to the University of Chicago for daylong visits. Due to attrition, the sample size at year 5 was 163 (constituting 71% of respondents; 32% of those initially surveyed). Data in CHASRS are available on age, gender, ethnicity, marital status, education, and income at baseline; also at both baseline and each of the follow-up visits, data are available on depressive symptoms, loneliness, social support, subjective well-being, psychiatric conditions, and psychiatric medications.

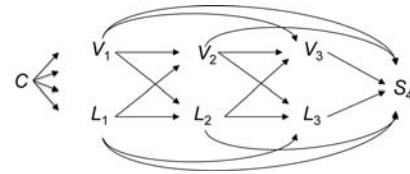
### Measures

Subjective well-being was assessed by using the 5-item Satisfaction with Life Scale (42) in which respondents rate each item on a scale from 1 to 7; the Satisfaction with Life

score is obtained by summing the 7 items; the measure has good discriminant and convergent validity (43). The 5 items are given in Table 1. Loneliness was assessed by using a revised version of the UCLA (University of California, Los Angeles) Loneliness Scale (R-UCLA), a 20-item questionnaire measuring perceived isolation, with each item scored 1–4 and the final loneliness score ranging from 20 to 80; the measure has been shown to have good construct validity (21, 44). So that estimates would be comparable, both subjective well-being and loneliness were standardized by dividing each measure by its standard deviation (which were 10.0 for loneliness on the R-UCLA and 6.6 for subjective well-being). The Center for Epidemiologic Studies–Depression (CES-D) Scale (45) was used to assess depressive symptoms. The CES-D is a 20-item measure; each item is rated by participants on a scale from 0 to 3, with the final depressive symptoms ranging between 0 and 60. The CES-D item assessing loneliness was eliminated to avoid overlap between depressive symptoms and loneliness. The measure (referred to as “CES-D-ML”) ranges from 0 to 57. Social support was measured by using the Interpersonal Support Evaluation List that consists of 12 statements for which participants rated each item between 1 and 4 (46, 47). Subscale scores were calculated for appraisal support, belonging support, and tangible support, and an overall social support score between 4 and 16 was computed by averaging the subscale scores. Psychiatric diagnosis was assessed by self-report according to whether participants indicated during a health interview that they had been told by a physician that they had emotional, nervous, or psychiatric problems. Antidepressant medications were coded as present or absent and included serotonin and norepinephrine reuptake inhibitors, selective serotonin reuptake inhibitors, monoamine oxidase inhibitors, and phenylpiperazine, tetracyclic, and tricyclic antidepressants.

### Models and estimation

Marginal structural models (33, 48) are models for the effects of hypothetical interventions on exposure at several points in time (i.e., effects corresponding to what would have happened had we been able to change the exposure). For example, we might consider the effect of loneliness at follow-ups 1, 2, and 3 (denoted by levels  $L_1$ ,  $L_2$ , and  $L_3$ , respectively) on subjective well-being at follow-up 4 (Figure 1). The resulting outcome, under such hypothetical interventions, is sometimes referred to as a counterfactual outcome. As discussed further below, levels of loneliness can be partially modified by cognitive therapy interventions. If we first consider loneliness as the exposure and subjective well-being as the outcome, the marginal structural model predicts average counterfactual outcome, possibly conditional on baseline covariates. Suppose, for example, we were to hypothetically consider setting, for the entire sample, loneliness at follow-up 1, 2, and 3 to levels  $L_1 = l_1$ ,  $L_2 = l_2$ , and  $L_3 = l_3$ , respectively. We will then let  $S_{l_1 l_2 l_3}$  denote the resulting outcome for subjective well-being at follow-up 4. The marginal structural model



**Figure 1.** Associations concerning the effects of loneliness on subjective well-being.  $C$  denotes baseline demographic characteristics along with baseline loneliness, depressive symptoms, subjective well-being, social support, psychiatric conditions, and psychiatric medications; it is assumed that the variables in  $C$  may affect all other variables;  $L_1$ ,  $L_2$ , and  $L_3$  denote loneliness at follow-up visits 1, 2, and 3, respectively;  $V_1$ ,  $V_2$ , and  $V_3$  denote depressive symptoms, subjective well-being, social support, and psychiatric conditions and psychiatric medications at follow-up visits 1, 2, and 3, respectively;  $S_4$  denotes final subjective well-being at follow-up 4. Time-dependent confounding is present because, for example,  $V_2$  is an effect of prior loneliness,  $L_1$ , but  $V_2$  also confounds the effect of subsequent loneliness,  $L_3$ , and final depressive symptoms,  $S_4$ .

then takes the form:

$$E[S_{l_1 l_2 l_3} | X = x] = \mu + \gamma x + \beta_1 l_1 + \beta_2 l_2 + \beta_3 l_3,$$

where the average counterfactual subjective well-being  $S_{l_1 l_2 l_3}$  conditional on baseline covariates  $x$  (e.g., possibly baseline loneliness or  $X$  could be empty) is modeled as a linear function of the levels to which loneliness is set at the subsequent follow-up visits. The linearity assumption is similar to those of other studies and is supported by visual inspection of the data. The effects on subjective well-being of joint interventions on loneliness at follow-ups 1, 2, and 3 are  $\beta_1$ ,  $\beta_2$ , and  $\beta_3$ , respectively, for a 1-standard deviation change in loneliness. The individual coefficients indicate the direct effects of loneliness at each time point independent of the effects at other time points. Note that, unlike conventional statistical models, the marginal structural model is a model for the counterfactual outcome,  $S_{l_1 l_2 l_3}$ , rather than the observed outcome. The model thus cannot be fit directly with regression, but it can be fit by using a weighting technique under certain no-unmeasured-confounding assumptions described below.

This weighting controls for confounding not through regression adjustment but instead by predicting the probability, conditional on past covariate history (including lagged values of subjective well-being and loneliness), of each individual's having the level of the exposure (e.g., loneliness) that was in fact present and then weighting each individual by the inverse of this conditional probability. With continuous exposures, as in the current application, conditional densities (rather than probabilities), obtained from linear regression, are used (33). A weight is calculated for the exposure at follow-ups 1, 2, and 3, and the overall weight for each individual is computed by taking the product of the weights at each period in time. The marginal structural model for the expected counterfactual outcomes conditional on possible baseline covariates is then fit by regressing the

observed outcome on the exposures at each time period and on baseline covariates but where each individual is weighted by the inverse-probability-of-treatment weights described above. For the effect of loneliness over time on final subjective well-being, control for confounding by weighting was done for age, gender, ethnicity, marital status, education, income at baseline along with baseline depressive symptoms, social support, loneliness, subjective well-being, psychiatric conditions, and psychiatric medications. Time-varying covariates are past values of subjective well-being, depressive symptoms, social support, psychiatric conditions, and psychiatric medications.

The weighting controls for the confounding due to the time-varying variables provided at each period  $k$ , the baseline covariates, and the history of the time-varying covariates up through time  $k - 1$  suffice to control for confounding of the effect of the exposure, loneliness at time  $k$ , on the final outcome. If this assumption holds, then the weighting technique will give consistent estimates of the parameters of the marginal structural model, thereby allowing inference about the effects on the outcome of hypothetically intervening on the exposure over time (33). More details concerning this technique are given elsewhere (33, 38).

In the analysis, the effect of hypothetical interventions at follow-up 1 did not have a significant effect on subjective well-being at follow-up 4 when also intervening at follow-ups 2 and 3. So as to better utilize the available data, a repeated-measures marginal structural model (48) was thus fit that simultaneously considers the effects of hypothetical interventions on loneliness at follow-ups 2 and 3 on subjective well-being at follow-up 4, along with the effects of hypothetical interventions on loneliness at follow-ups 1 and 2 on subjective well-being at follow-up 3. The model that was fit takes the form:

$$E[S_{l_{t-1}l_{t-2}}(t)] = \mu + \lambda t + \beta_1 l_{t-1} + \beta_2 l_{t-2}$$

for  $t = 3$  and  $t = 4$ , where  $S_{l_{t-1}l_{t-2}}(t)$  is subjective well-being at follow-up  $t$  that would have resulted under hypothetical joint interventions to set loneliness at follow-up visits  $t - 1$  and  $t - 2$  to levels  $l_{t-1}$  and  $l_{t-2}$ , respectively. The effects on subjective well-being at time  $t$  of joint interventions on loneliness at follow-up visits  $t - 1$  and  $t - 2$  are  $\beta_1$  and  $\beta_2$ , respectively, for a 1-standard deviation change in loneliness. The weights for fitting this repeated measures marginal structural model vary over time and, at a particular time  $t$ , consist of the product of the weights up through time  $t$  (38, 48). Weights were truncated at the 1st and 99th percentiles of the weight distribution, as recommended by Cole and Hernán (49) to improve precision. Analyses were conducted to take into account censoring and missingness by using inverse-probability-of-censoring weighting using age, gender, race, and baseline loneliness (variables available for almost everyone) as predictors. The technique is described in general by Robins et al. (33) and for this particular marginal structural model by VanderWeele et al. (38). Robust standard errors are used to take into the weighting (33); effect estimates and standard errors are for the study sample. Sensitivity analysis (50) was used to

**Table 2.** The Effects on Subjective Well-being of Hypothetical Interventions on Loneliness 1 and 2 Years Prior to Assessment of Subjective Well-being<sup>a</sup>

Parameter	$\beta$ Coefficient (Estimate)	Standard Error	95% Confidence Interval	P Value
2 years prior	-0.039	0.069	-0.175, 0.098	0.575
1 year prior	-0.291	0.075	-0.440, -0.144	<0.001

<sup>a</sup> Adjustment for baseline and time-varying covariates is done by weighting; measures are effects in standard deviations of subjective well-being per standard deviation change in loneliness.

assess the extent of the unmeasured confounding that would be needed to explain away effect estimates.

After fitting a marginal structural model for the effects of hypothetical interventions on loneliness, we fit a similar marginal structural model for the effects on loneliness of hypothetical interventions on subjective well-being. Once again, the effect of an hypothetical intervention on subjective well-being at follow-up 1 did not have a significant effect on loneliness at follow-up 4 when also intervening at follow-ups 2 and 3. We therefore again fit a repeated-measures marginal structural model. We let  $L_{s_{t-1}s_{t-2}}(t)$  denote the level of loneliness at follow-up  $t$  that would have resulted under hypothetical joint interventions to set subjective well-being at follow-up visits  $t - 1$  and  $t - 2$  to levels  $s_{t-1}$  and  $s_{t-2}$ , respectively. The marginal structural model then takes the form:

$$E[L_{s_{t-1}s_{t-2}}(t)] = \mu + \lambda t + \beta_1 s_{t-1} + \beta_2 s_{t-2}.$$

The effects on loneliness at time  $t$  of joint interventions on subjective well-being at follow-up visits  $t - 1$  and  $t - 2$  are  $\beta_1$  and  $\beta_2$ , respectively, for a 1-standard deviation change in subjective well-being. For this second marginal structural model, the time-varying covariates were past values of loneliness, depressive symptoms, social support, psychiatric conditions, and psychiatric medications.

## RESULTS

At baseline, the study sample was characterized as follows: 52% female; mean age of 57.4 years; 61.3% married; 37.3% non-Hispanic Caucasian, 34.4% African American, and 28.3% Hispanic American; mean years of education of 13.5; and mean household income of \$67,728. The mean baseline level for loneliness on the R-UCLA scale was 36.1; the mean baseline subjective well-being on the Satisfaction with Life Scale was 23.7; the mean level of depressive symptoms on the CES-D-ML scale was 9.8; 12.7% reported psychiatric medications at baseline; and 12.4% reported psychiatric diagnosis at baseline.

Table 2 presents results for the effects over time of loneliness on subjective well-being. The coefficients reported give the effects (per standard deviation in loneliness change) of hypothetical joint interventions on loneliness 1

**Table 3.** The Effects on Loneliness of Hypothetical Interventions on Subjective Well-being 1 and 2 Years Prior to Assessment of Loneliness<sup>a</sup>

Parameter	$\beta$ Coefficient (Estimate)	Standard Error	95% Confidence Interval	P Value
2 years prior	-0.126	0.052	-0.223, -0.030	0.011
1 year prior	-0.257	0.047	-0.361, -0.153	<0.001

<sup>a</sup> Adjustment for baseline and time-varying covariates is done by weighting; measures are effects in standard deviations of loneliness per standard deviation change in subjective well-being.

and 2 years prior to assessing subjective well-being. The analysis suggests that interventions on loneliness only in the immediate year prior (not on 2 years prior) would have an effect on subjective well-being. Under the model assumptions, the estimates indicate that intervening to decrease loneliness by 1 standard deviation 1 year prior to assessing subjective well-being would result in approximately a 0.29-standard deviation increase in subjective well-being (95% confidence interval (CI): 0.14, 0.44;  $P < 0.001$ ). The estimate for intervening to decrease loneliness by 1 standard deviation 2 years prior to assessing subjective well-being was a 0.04-standard deviation increase in subjective well-being (95% CI: -0.10, 0.17;  $P = 0.58$ ), when also intervening on loneliness 1 year prior to assessing subjective well-being. The estimate for 2 years prior is not statistically significant. Sensitivity analysis indicates that, to explain away the estimate of the effect of loneliness on subjective well-being, a binary unmeasured confounder that differed in prevalence by 30% for each standard deviation difference in loneliness would have to have an effect on subjective well-being of 0.97 standard deviations.

Table 3 presents results for the effects over time of subjective well-being on loneliness. The coefficients give the effects (per standard deviation in subjective well-being change) of hypothetical joint interventions on subjective well-being 1 and 2 years prior to assessing loneliness. The analysis suggests that interventions on subjective well-being in both of the prior 2 years would have effects on loneliness. Under the model assumptions, the estimates indicate that intervening to increase subjective well-being by 1 standard deviation 1 year prior to assessing loneliness would result in approximately a 0.26-standard deviation decrease in loneliness (95% CI: 0.15, 0.36;  $P < 0.001$ ). Intervening to increase subjective well-being by 1 standard deviation 2 years prior to assessing loneliness would result in approximately a 0.13-standard deviation decrease in loneliness (95% CI: 0.03, 0.22;  $P = 0.01$ ), even when also intervening on subjective well-being 1 year prior to assessing loneliness. A joint intervention to increase subjective well-being by 1 standard deviation relative to what it otherwise would have been, both 1 year and 2 years prior to assessing loneliness, would result in a  $0.257 + 0.126 = 0.383$  standard deviation decrease in loneliness (95% CI: 0.268, 0.499;  $P < 0.001$ ). Sensitivity analysis indicates that, to

explain away the estimate of the effect of subjective well-being 1 year prior on loneliness, a binary unmeasured confounder that differed in prevalence by 30% for each standard deviation difference in subjective well-being would have to have an effect on loneliness of 0.87 standard deviations.

## DISCUSSION

In this study, we have examined the reciprocal effects between subjective well-being and loneliness. Using longitudinal data, we have seen that the magnitude of both of these effects is fairly substantial. We have used marginal structural model techniques from causal inference to attempt to parse out these effects, examine their persistence, and control for time-varying confounding. Importantly, the reciprocal effects remain even after control for time-varying depressive symptoms, objective social support, and psychiatric conditions and medications. As discussed further below, conclusions are always tentative with observational data, but the analyses here control for plausible competing hypotheses and provide considerable evidence for feedback in the form of reciprocal effects between subjective well-being and loneliness.

Both loneliness (1–13) and subjective well-being (15, 51) have effects on health and mortality. Developing interventions to alter these psychological constructs will have important consequences for health. A recent meta-analysis (52) indicated that interventions to modify loneliness exert modest effects in mitigating feelings of loneliness. Loneliness interventions with the largest effects (roughly 0.6 standard deviations) were those using a cognitive-behavioral approach (52). A meta-analysis on well-being interventions (53) also suggested that these could have modest effects. The analyses here indicate that approaches that increase either an individual's sense of subjective well-being or that mitigate feelings of loneliness may help prevent any negative feedback that may occur between the 2. Interventions on 1 of these constructs would likely also alter the other, further enhancing the health benefits.

Our results raise questions about the mechanisms governing the feedback that occurs between loneliness and subjective well-being that merit further study. A number of mechanisms have been hypothesized in the literature. One of the pernicious effects of loneliness is that it alters people's social cognition, making them more suspicious of and negative toward other individuals (54). Conversely, research by Isen (55) indicates that finding a coin in a pay phone is sufficient to make a person happy and to promote more positive, altruistic interpersonal interactions. Thus, whereas loneliness may affect subjective well-being through its effects on emotions and moods, subjective well-being itself may influence both objective and subjective aspects of social relationships. Cacioppo et al. (56) examined the influence of an individual's loneliness on the loneliness of other individuals in a social network. The number of days an individual was lonely each week was found to influence the levels of loneliness of friends, neighbors, and spouses. One mechanism for this sort of social influence, consistent with our results here, is that loneliness of 1

individual may lead to lower subjective well-being and potentially subsequently less satisfying social relationships contributing to the loneliness of other individuals (17).

Although we found evidence for an effect in both directions, loneliness 1 year prior to assessing subjective well-being had an effect, whereas subjective well-being both 1 year prior and 2 years prior to the final assessment of loneliness seemed to influence loneliness. These differences are not attributable to differences in temporal stability, as the 1-, 2-, and 3-year temporal stability for loneliness and subjective well-being were 0.71 versus 0.72, 0.71 versus 0.69, and 0.62 versus 0.62, respectively.

The motivational effects of loneliness and subjective well-being may be a key consideration in understanding the asymmetry. Subjective well-being reflects a positive state that motivates people to continue what they are doing to maintain this state. Mauss et al. (57) noted that happiness is usually defined in terms of personal gain in Western contexts, and they reasoned that the pursuit of an explicit goal to raise one's subjective well-being could have the reverse effect because it would lead to more selfish activities, damage connections with others, and make them lonelier and less happy. Subjective well-being may have long-term (ameliorative) effects on loneliness, not because people are trying to pursue their own subjective well-being, but because the behavior they displayed that led to their happiness is maintained.

In contrast to subjective well-being, loneliness is an *aversive* state that evolved as a signal—like physical pain, hunger, and thirst—to change behavior (58). Being motivated to change may be sufficient to lead people to change their behavior. Thus, although loneliness and subjective well-being are equally temporally stable, the motivation of the latter is to maintain what one has been doing, whereas the motivation of the former is to change one's behaviors. This difference may potentially be responsible for the differential persistence of the effects of loneliness on subjective well-being and of subjective well-being on loneliness, though further evidence would be needed to confirm this.

The analyses here made use of observational longitudinal data and, like analyses of all observational studies, are subject to limitations. First, although we have controlled for a number of sociodemographic variables and time-varying confounding variables, analyses with observational data are always potentially subject to additional unmeasured confounding. Given the magnitude of the effects reported here and the control for a number of measured variables, along with our sensitivity analysis, we think it is unlikely that the effects reported here are due entirely to unmeasured confounding. Second, our analyses here presuppose that the models used were correctly specified, although the marginal structural model approach we used here uses somewhat weaker assumptions than the structural equation modeling literature (38, 39).

Finally, the longitudinal data used in CHASRS have annual measures of the psychological constructs used in the analyses. Although the longitudinal nature of the data allows us to pursue questions that would not be possible to address with cross-sectional data, the reality of the psychological processes underlying the associations of interest is

certainly more complex than the instruments and the frequency of measurements are able to capture. Loneliness and subjective well-being (as well as depressive symptoms, social support, psychiatric medications, and so on), although relatively stable over 1-year intervals (correlations across 1-year intervals range from 0.70 to 0.78 for subjective well-being and from 0.76 to 0.84 for loneliness), are in fact continuously evolving. We have used models that effectively presuppose annual exposure periods. Our finding of an asymmetric association with subjective well-being affecting loneliness for both of 2 prior years but loneliness affecting subjective well-being for 1 year prior can thus only be taken to be tentatively established. Methodological work has begun to explore continuous time exposures that are sampled discretely (59), but this literature has not yet progressed to the point where it is applicable to the data structure at hand. Our analyses constitute an approximation of a complex reality. We do nevertheless believe that our analyses give some indication of the relative magnitude and persistence of the reciprocal effects between loneliness and subjective well-being.

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