Preliminary investigation of the regulatory loop of loneliness and the protective role of self-esteem – a cross-sectional study

Andrej Skoko[1] · Janko Kaeser[2] · Noëmi Seewer[1] · Tobias Krieger[1]

Abstract

As a major public health issue, chronic loneliness has been associated with increased mortality and impaired physical and mental health. The proposed model by Cacioppo and Hawkley (*Trends in Cognitive Sciences*, *13*(10), 447–454, 2009) pictures the emergence and maintenance of chronic loneliness as a vicious cycle containing cognitive and behavioral aspects. As a potential source of resilience, self-esteem has been shown to have buffering effects on loneliness. This study aimed to investigate the central relationships between the components within the regulatory loop of loneliness and the potential buffering effect of self-esteem. In this study, a community sample of 436 adult participants completed measures of loneliness, interpretation bias in social situations, social avoidance behavior, self-esteem, and important covariates (including depressive and social anxiety symptoms and social network size). First, we tested bivariant correlations. Subsequently, we tested three mediation models representing the regulatory loop of loneliness. Lastly, we tested moderated mediation models with self-esteem as a moderator. Loneliness was positively associated with interpretation bias and social avoidance and negatively with self-esteem. Indirect effects in all three mediation models testing the regulatory loop were positive and strongly significant. Self-esteem was a significant moderator in the mediation models, with higher levels of self-esteem attenuating the indirect effect of loneliness on interpretation bias. These effects held even when controlled for relevant covariates, such as depressive and social anxiety symptoms. This study gives preliminary empirical support for the proposed model of chronic loneliness by Cacioppo and Hawkley (*Trends in Cognitive Sciences*, *13*(10), 447–454, 2009) and the potential buffering effect of self-esteem. Hence, our results support the notion of addressing maladaptive social cognitions and maladaptive social behavior to effectively reduce chronic loneliness and strengthen self-esteem as a protective factor.

Keywords Cognitive model · Loneliness · Mediation · Moderation · Self-esteem

Introduction

Defined as a discrepancy between the desired and actual quality and/or quantity of social relationships (Peplau & Perlman, 1982), loneliness is a common phenomenon in clinical practice and the public. It represents an emotional and distressing state stemming from the subjective perception of social isolation or when existing relationships fail to meet one's expectations (Heinrich & Gullone, 2006). This emotional state is underlined by an inherent need to belong, comprising a desire to form and maintain positive, lasting, and significant interpersonal relationships (Baumeister & Leary, 1995). Over the years, the attention surrounding loneliness has steadily grown and findings have linked prolonged loneliness to increased mortality and impaired physical and mental health, highlighting loneliness as a global health priority (Lim et al., 2023).

Regulatory loop of loneliness

Even though prolonged loneliness has been associated with adverse effects on health, transient feelings of loneliness can have an adaptive function. From an evolutionary standpoint, loneliness can be understood as a "social thirst" (Cacioppo

✉ Andrej Skoko
andrej.skoko@unibe.ch

[1] Department of Clinical Psychology and Psychotherapy, University of Bern, Bern 3012, Switzerland

[2] University Hospital of Child and Adolescent Psychiatry and Psychotherapy, University of Bern, Bern 3000, Switzerland

et al., 2014), as it can function as a signal pointing to an unfulfilled social need. Therefore, loneliness can promote adaptive behaviors such as reconnecting with people from existing relationships or forming new ones (Cacioppo et al., 2014). Hence, loneliness can be a healthy reaction, indicating that adjustments must be made regarding social life (Cacioppo et al., 2014; Qualter et al., 2015). However, the question arises of how this adaptive nature of loneliness seems to vanish over a more extended period. Cacioppo and Hawkley (2009) have suggested that loneliness may affect human cognition in maladaptive ways over time. Accordingly, feelings of loneliness arise from experiencing social isolation and/or interpersonal rejection, which can lead to a motivational conflict. The desire to reaffiliate with others and simultaneously the motive to protect oneself from social threats arise, which is assumed to lead to hypervigilance toward social threats and a distorted perception of social situations (Qualter et al., 2015). Especially ambiguous social situations seem to be interpreted as more threatening by lonely people (Qualter et al., 2013). This appears to be based on biased cognitions, which in turn may lead to counterproductive social behaviors and, consequently, reexperiencing negative social situations and loneliness (Cacioppo & Hawkley, 2009; Qualter et al., 2015).

In their comprehensive review, Spithoven et al. (2017) have examined cognitive aspects of the regulatory loop postulated by Cacioppo and Hawkley (2009) that may lead to prolonged loneliness. They have gathered existing evidence on the relationship between cognitive aspects and loneliness and showed that lonely individuals seem to exhibit negative biases in several areas of social information processing. This distorted information processing appears to manifest itself in an increased attentional focus on socially threatening stimuli, negative evaluations of oneself and others, increased avoidance goals, and enhanced social avoidance behavior, among others (Spithoven et al., 2017). However, most of the findings seldomly include several aspects of the regulatory loop simultaneously (Lau et al., 2021; Okruszek et al., 2021; van Winkel et al., 2017). Hence, what the relationships between the components of the regulatory loop may look like and if the proposed circular structure of the vicious cycle can be empirically confirmed remain to be seen.

Self-esteem as a potential buffer

Qualter et al. (2015) have extended the regulatory loop with an alternate pathway out of this vicious circle. Arguing for the adaptive nature of loneliness, they propose a possible crossway before the maladaptive (biased) interpretations and the counterproductive behavioral enactment. Following the activated reaffiliation motive, a phase of social withdrawal to monitor social situations and potential social threats can either lead to a regulation of behavior to reconnect or the abovementioned maladaptive cycle (Qualter et al., 2015). However, the question arises, what could promote this adaptive pathway.

In their review, Heinrich and Gullone (2006) highlighted that one of the most pertinent issues of psychosocial problems surrounding loneliness might be its consistent association with low self-esteem in several findings. Similarly, a longitudinal study has not only found negative between-person associations between loneliness and self-esteem but negative within-person effects of loneliness on self-esteem over time as well (Ti et al., 2022). Besides these negative associations with loneliness, self-esteem can also have its merits. At its core, self-esteem can be understood as a global evaluation of the self (Baumeister et al., 2003). High self-esteem is predictive of one's success and well-being in several life domains, even after controlling for prior levels of self-esteem and success (Orth & Robins, 2014). Previous studies have also shown that high self-esteem had not only a buffering effect on loneliness itself but also the effects of loneliness on other constructs, such as life satisfaction and symptoms of depression and anxiety (Baumeister et al., 2003; Çivitci & Çivitci, 2009; Kong & You, 2013; Rossi et al., 2020). This begs the question if self-esteem could play a crucial role in the regulatory loop of loneliness.

While no studies have taken a closer look at this question, other studies have examined the connection between self-esteem, social information processing, and perceived social rejection, which arguably can be seen as conceptual parts of the regulatory loop of loneliness (Rokach, 1988). Numerous of those studies indicate that high self-esteem might be a source of resilience when facing social rejection, which is closely linked to loneliness (Qualter et al., 2015). More specifically, self-esteem seems to moderate the relationship between social rejection and its cognitive evaluations (Ford & Collins, 2010, 2013; Gyurak & Ayduk, 2007; Kashdan et al., 2014). Therefore, the moderation between social rejection and its cognitive evaluation could be similarly found between loneliness and social cognitions. The findings of Geukens et al. (2022) support this notion as they found higher loneliness connected to elevated fear of negative evaluation and lower self-esteem. With the postulated regulatory loop of loneliness in mind, self-esteem might serve as a buffer for the relationship between feelings of loneliness and biased social information processing. Therefore, with self-esteem potentially attenuating this relationship, the chances of engaging in social situations with less avoidance tendencies might grow due to less biased interpretations of social situations.

The present study

The present study's first aim is to investigate central relationships within the regulatory loop of loneliness. Accordingly, we expect positive relationships between the three components: loneliness, negative interpretation bias in social situations, and social avoidance behavior. These hypotheses account for the reinforcement of loneliness

through the behavioral confirmation of lonely individuals' negative social expectations (Cacioppo & Hawkley, 2009). Secondly, to account for the cyclical structure in which these components lie, three simple mediation models, corresponding to the ones depicted in Fig. 1, are tested containing those three constructs, where we expect significant indirect effects in all models. The third aim is to investigate if self-esteem moderates the relationship between loneliness

Fig. 1 Conceptual models of the proposed relationships in the regulatory loop of loneliness. *Note.* The solid circles show the postulated signs of the path coefficients corresponding to the arrows
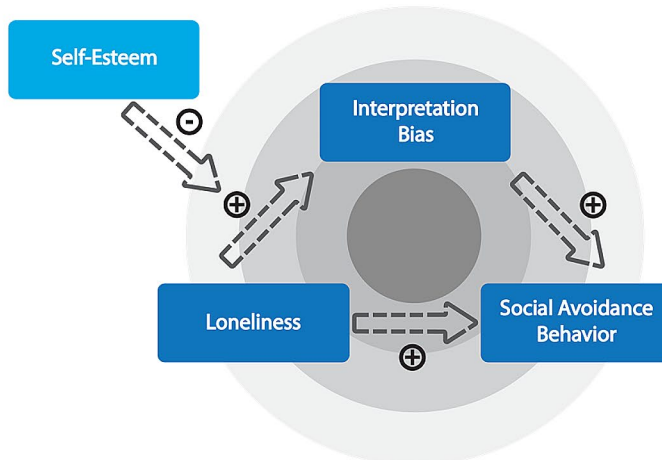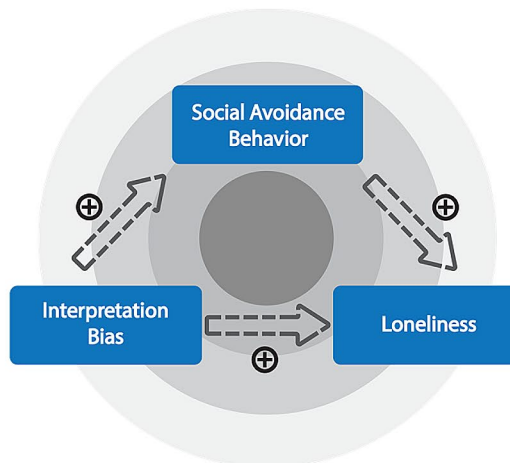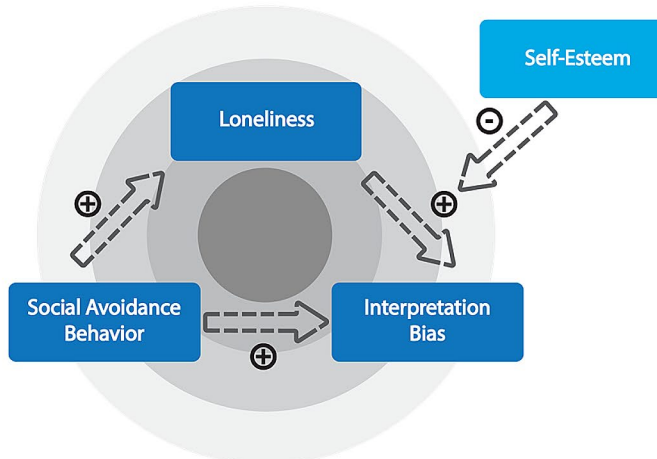
and interpretation bias, with higher self-esteem weakening this connection. Finally, the three conceptual models (see Fig. 1) are examined to test the moderating effect of self-esteem on the mediations. Model 1 pictures the relationship between loneliness and social avoidance behavior, mediated by interpretation bias, with self-esteem as a moderator of the relationship between loneliness and interpretation bias. In Model 2, the relationship between interpretation bias and loneliness is pictured, mediated by social avoidance behavior. Lastly, Model 3 pictures the relationship between social avoidance behavior and interpretation bias mediated by loneliness. Since loneliness serves as a predictor for interpretation bias in Model 3, this path also includes the moderating influence of self-esteem.

Methods

Participants and procedure

The sample of this cross-sectional study consisted of 436 German-speaking adult participants from the general public (72.5% females; age (years): $M(SD) = 32.24$ (15.25), $Mdn = 25.5$, range = 18 – 82; occupation: 67% employed, 33% unemployed; highest educational degree: 63.1% university/university of applied sciences, 11.7% higher technical college, 15.1% apprenticeship, 9.9% compulsory school and 0.2% no degree; relationship status: 55.5% unattached, 44.5% in a relationship or married), who completed an online survey ($N = 424$) or a paper–pencil questionnaire ($N = 12$). Participants were recruited through personal connections, social media, or E-mail directories, and the data collection was fully anonymized. The data collection took place between November 2019 and June 2020. The inclusion criteria were age above 18 years and the ability to understand and write German since the survey was in German. Since we aimed to preliminarily test the dynamics of the cognitive model and the buffering effect of self-esteem in the general public, we did not recruit participants with a specific community in mind. The online survey contained two bogus items designed to detect random responses. At the beginning of the survey, the participants gave their informed consent. After completing the survey, participants could enter a gift card drawing.

Measures

Loneliness

Loneliness was measured with the German 9-item version (Luhmann et al., 2016) of the UCLA loneliness scale (UCLA-LS; Russell, 1996) with item translations by Döring and Bortz (1993). Sample items are: "How often do you feel that you lack companionship?", "How often do you feel that you have a lot in common with the people around you?". The items were rated on a Likert scale from 1 (never) to 4 (always). This short version showed sufficient convergent validity (Luhmann et al., 2016). For the analyses, the mean score over all items was calculated and ranged from 1 to 4 with higher scores reflecting higher levels of loneliness.

Interpretation bias

Interpretation bias in social situations was assessed with the respective subscale of the Interpretation and Judgmental Questionnaire (IJQ; Brettschneider et al., 2015; Voncken et al., 2007). The scale consists of social events with positive, ambivalent, mildly negative, or profoundly negative valence. Five scripts were presented for each valence. Four interpretations for every event were used as the response format, ranging from positive, ambiguous, and mildly negative to profoundly negative, which the participants had to rate for plausibility ("Which of the four answers seems most plausible/appropriate to you?") by ranking them from one to four. First, the mean rank of the profoundly negative interpretation was calculated over situations with the same valence, resulting in four subscales. The score is the mean rank given to the profoundly negative interpretation of the scenarios and ranges between 1 and 4. After recoding higher score indicates more negatively biased processing.

Social avoidance behavior

Social avoidance behavior was measured with a subscale from the Cognitive-Behavioral Avoidance Scale (CBAS; Ottenbreit & Dobson, 2004; Röthlin et al., 2010). For this study, the 8-item behavior social subscale was used (e.g., "I tend to make up excuses to get out of social activities," "I avoid attending social activities"). The rating consisted of a five-point Likert scale ranging from 1 (not at all true for me) to 5 (completely true for me). The mean score over all items ranging from 1 to 5 was used, with higher scores reflecting higher levels of social avoidance behavior.

Self-esteem

Self-esteem was measured with the 10-item revised German version of the Rosenberg Self-Esteem Scale (RSES; Rosenberg et al., 1989; von Collani & Herzberg, 2003). The questionnaire was answered with a Likert-Scale ranging from 0 (strongly agree) to 3 (strongly disagree) (e.g., "I feel that I'm a person of worth, at least on an equal plane with others", "I feel I do not have much to be proud of"). The

mean score over all items ranging from 0 to 3 was used with higher scores reflecting higher levels of self-esteem.

Covariates

As for the covariates, we assessed depressive symptoms with the sum score of 9-item depression module of the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001; Löwe et al., 2004) symptoms of social interaction anxiety with the sum score of the short-form of the Social Interaction Anxiety Subscale (SIAS-6; Peters et al., 2012), mobility with the corresponding subscale of the Patient Questionnaire for Medical Rehabilitation (IRES-4; Bührlen et al., 2005; Wirtz et al., 2005), social network with the social network index (SNI; Berkman & Syme, 1979; Härtel et al., 1988).

Loneliness is a mainly subjective phenomenon, distinct from objective isolation (Cornwell & Waite, 2009; Peplau & Perlman, 1979). Hence, the relationships presented here should hold even when controlling for objective factors such as the social network size. Reduced mobility can also be such a factor, limiting socialization opportunities, especially in the elderly (Cohen-Mansfield & Parpura-Gill, 2007). Furthermore, there have been bidirectional associations between loneliness and symptoms of mental disorders such as depression or anxiety disorders (Danneel et al., 2020; Maes et al., 2019a, b; Santini et al., 2020; Vanhalst et al., 2012). To account for these two factors, potentially leading to objective social isolation and the presence of symptoms of depression or social anxiety, all regression models were calculated with social network size, mobility, and symptoms of depression and social interaction anxiety as covariates. Regarding gender differences, on the one hand, men have been shown to report more loneliness when indirect measures were used, as in the current study (Barreto et al., 2021). On the other hand, a meta-analysis has shown gender differences in loneliness to be close to zero (Maes et al., 2019a, b). Nevertheless, we included gender as a covariate to account for a potential influence and due to our predominantly female sample (0 = female, 1 = male). Furthermore, age was incorporated as a covariance even though it has not been shown to be a predictor of loneliness by itself (Luhmann et al., 2023). See Appendix A for detailed descriptions of the questionnaires used to assess the covariates.

Statistical analyses

Bivariate Pearson correlations were computed to assess the relationship between loneliness, interpretation bias in social situations, and social avoidance behavior. Mediation, moderation, and conditional process analysis were conducted using the PROCESS macro by Hayes (2018) for SPSS. Data cleaning, descriptive and inferential analyses, and graphics

production were performed with SPSS 28.0 (IBM Corp., 2021) and R 4.1.2 (R Core Team, 2022). To test the presented models, this study followed the approach of Hayes (2018), firstly separating tests of individual components and secondly integrating testing of all components using conditional process analysis. For this reason, six regression-based analyses were conducted in three stages. First, three simple mediation models were tested. They correspond to the three conceptual models in Fig. 1 without the moderating role of self-esteem in Model 1 and Model 3. Second, a simple moderation model was tested where the effect of loneliness on interpretation bias was moderated by self-esteem. Third, for the two conceptual models in Fig. 1 containing loneliness as a predictor for interpretation bias (Model 1 and Model 3), the moderation by self-esteem was integrated into the mediation models. This step was only conducted if all previous analyses were consistent with the hypotheses. In these so-called conditional process analyses, the unconditional direct and conditional indirect effects were estimated and tested using inferential methods. All bootstrap confidence intervals were based on 10′000 samples.

Results

Table 1 presents the means, standard deviations, ranges, Cronbach's alphas as indicators of internal consistency and intercorrelations for the measures. All correlations were significant and consistent with the first three hypotheses.

Simple mediation models

Following Model 1 of the conceptual models (see Fig. 1), we first evaluated interpretation bias as a mediator of the relationship between loneliness and social avoidance behavior. The corresponding regression equations and a visual representation of the statistical model, including the standardized path coefficients, are displayed in Fig. 2. Loneliness affected the reported social avoidance behavior directly as well as indirectly mediated by interpretation bias. Individuals with higher levels of loneliness also reported a higher interpretation bias, and individuals with a higher interpretation bias also reported more social avoidance behavior. The 95% bootstrap confidence interval for the indirect effect was above zero, which indicates that a high level of loneliness partially leads to social avoidance behavior through social interpretation bias.

The second simple mediation model corresponding to Model 2 tested if the positive relationship between interpretation bias and loneliness was mediated through social avoidance behavior. Figure 2 displays the corresponding regression equations and a visual representation of the

Table 1 Descriptive statistics and correlations

Variables	M	SD	Range	1	2	3	4	5	6	7	8	9	10
1 Loneliness	1.98	0.49	1.00–3.67	(.86)									
2 Interpretation Bias	1.42	0.39	1.00–3.30	.47	(.86)								
3 Social Avoidance Behavior	2.01	0.78	1.00–4.50	.54	.47	(.88)							
4 Self-Esteem	2.14	0.61	0.00–3.00	-.55	-.56	-.49	(.91)						
5 Social Network Size	2.48	0.91	0–4	-.34	-.21	-.19	.21	-					
6 Mobility	8.43	1.61	2–10	-.25	-.19	-.25	.22	.14	(.72)				
7 Depressive Symptoms	6.70	4.76	0–27	.52	.46	.50	-.62	-.25	-.32	(.84)			
8 Social Interaction Anxiety Symptoms	4.30	3.95	0–24	.51	.52	.64	-.51	-.15	-.16	.54	(.80)		
9 Gender	-	-	-	-.10	.07	-.02	-.04	-.07	-.11	.09	.01	-	
10 Age	32.24	15.25	18–82	.07	-.15	-.04	.14	-.11	-.12	-.14	-.22	-.16	-

Cronbach's alphas are provided in parentheses on the diagonal. The 95% confidence intervals of the correlations that are displayed in bold do not contain zero. $N = 436$

statistical model, including the standardized path coefficients. Interpretation bias affected loneliness directly as well as indirectly mediated by social avoidance behavior. Individuals who reported higher interpretation bias showed more social avoidance behavior, and individuals with more social avoidance behavior exhibited higher levels of loneliness. The 95% bootstrap interval for the indirect effect was above zero, which indicates that the effect of interpretation bias on loneliness is partially mediated by social avoidance.

The third simple mediation model corresponding to Model 3 tested the mediation of social avoidance behavior on interpretation bias by loneliness without considering the moderation by self-esteem. The corresponding regression equations and a visual representation of the statistical model, including the standardized path coefficients, are displayed in Fig. 2. Social avoidance behavior affected interpretation bias directly as well as indirectly mediated by loneliness. More social avoidance behavior led to a higher degree of loneliness, and higher loneliness led to higher levels of interpretation bias. The 95% bootstrap confidence interval for the indirect effect was above zero, which indicates that the indirect effect of social avoidance behavior on interpretation bias mediated by loneliness is significant. For more detailed results of all mediation models, see Appendix B.

Simple moderation model

The regression analysis results investigating the moderation of the effect of loneliness on interpretation bias by self-esteem can be found in Appendix C. Of primary interest was the significant regression coefficient of the interaction term Loneliness × Self-esteem ($b_3 = -0.08$, $p = 0.016$). Consequently, the effect of loneliness on interpretation bias depended on the level of self-esteem. Figure 3 shows that a higher degree of loneliness was associated with more interpretation bias; this connection was higher in individuals with low self-esteem ($M - 1\ SD$; Simple Slope = 0.22) than in individuals with high self-esteem ($M + 1\ SD$; Simple Slope = 0.06).

Conditional process analyses

The conditional process analysis aimed to integrate the initial moderation analysis in the simple mediation models. The condition that all previous analyses were consistent with the hypotheses was met. In Models 1 and 3 in Fig. 1, loneliness serves as a predictor of interpretation bias. Accordingly, the moderating effect of self-esteem on the relationship between loneliness and interpretation bias can be incorporated into these models using the conditional process analysis by Hayes (2018).

Figure 4 visualizes the corresponding unstandardized path coefficients and the conditionality of the indirect effect of loneliness on social avoidance behavior through interpretation bias, where c' represents the unconditional direct effect of loneliness on social avoidance behavior and a_3b represents the slope of the conditional indirect effect (Model 1). The 95% bootstrap confidence interval of the slope of the conditional indirect effect ($a_3b = $ -0.02) was around zero [−0.05, 0.00]. Hence, the indirect effect of loneliness on social avoidance behavior mediated by interpretation bias was not significantly dependent on the level of self-esteem. However, the probing with 95% bootstrap confidence intervals for low ($M - SD$), average (M), and high self-esteem ($M + SD$) revealed that the conditional indirect effect of loneliness on avoidance behavior mediated through interpretation bias was only significant when self-esteem was low.

The corresponding unstandardized path coefficients and the conditionality of the indirect effect of social avoidance behavior on interpretation bias through loneliness are depicted in Fig. 4 (Model 3). In this figure, c' represents the unconditional direct effect of avoidance behavior on cognitive bias, and ab_3 represents the slope of the conditional indirect effect. The 95% bootstrap confidence interval of the indirect effect ($ab_3 = $ -0.02) was below zero [−0.04, −0.00]. Therefore, the indirect effect of avoidance behavior on interpretation bias mediated by loneliness depended on the level of self-esteem. Higher levels of avoidance behavior led to more loneliness and, thus, higher interpretation bias. This connection was stronger in individuals with low self-esteem ($M - SD$; Simple Slope of the indirect effect: 0.02) in comparison to individuals with high self-esteem ($M + SD$; Simple Slope of the indirect effect: 0.00). The probing with 95% bootstrap confidence intervals for low ($M - SD$), moderate (M), and high self-esteem ($M + SD$) revealed that the conditional indirect effect of avoidance behavior on interpretation bias mediated through loneliness was only significant when self-esteem was low and moderate. For more detailed results of all conditional process analyses, see Appendix D.

Discussion

The aims of the present study were first to test the relationships between the components of the postulated regulatory loop of loneliness and second to test the buffering effect of self-esteem on the relationship between loneliness and interpretation bias. The results support our hypotheses concerning the relationships between loneliness, interpretation bias in social situations, and social avoidance behavior. All pathways of the three simple mediation models were significantly positive even when controlling for a variety of covariates, which provide preliminary support for the view of the regulatory loop where the components seem to reinforce each other, leading to a potentially vicious cycle of loneliness (Cacioppo & Hawkley, 2009).

As for the buffering effect of self-esteem, results confirmed self-esteem as a moderator of the positive relationship between loneliness and interpretation bias, with higher self-esteem attenuating this connection. The probing of the interaction revealed that the effect of loneliness on interpretation bias ceased to be significant when self-esteem reached a certain level. Regarding the conditional process analyses, the results support our hypotheses only to a certain degree. On the one hand, the conditional indirect effect of loneliness on social avoidance behavior partially mediated by interpretation bias was not dependent on self-esteem (Model 1). However, probing the conditional indirect effect revealed a significant dependency of low self-esteem on the mediation. On the other hand, the indirect effect of avoidance behavior on interpretation bias partially mediated by loneliness was dependent on the level of self-esteem (Model 3). The probing revealed that the conditional indirect effect was only significant for low and medium levels of self-esteem. Taken together, the results suggest that low self-esteem increases the effects of loneliness on interpretation bias in social situations, and high self-esteem seems to buffer the effects of loneliness on interpretation bias.

All those results emerged even when accounting for social network size, mobility, gender, age, symptoms of depression, and social interaction anxiety. Interestingly, we observed that the standardized coefficients from symptoms of depression and social interaction anxiety to loneliness in all three models were, in most cases, significant, which underlines the similarities between the constructs but also the importance of distinguishing them from each other (Danneel et al., 2020). Nevertheless, this shows the need to incorporate these two constructs when investigating loneliness.

## Preliminary support for the regulatory loop of loneliness

The results add further preliminary evidence to the proposed relationships of the conceptual model of loneliness introduced in this study (Cacioppo et al., 2009; Qualter et al., 2015). Compared to non-lonely individuals, lonely individuals seemed more prone to distorted interpretations of social situations. Furthermore, these biased interpretations in social situations mediated the relationship between loneliness and social avoidance behavior. The altered social-cognitive processing of lonely individuals might lead them to engage in different behavioral response patterns than non-lonely individuals, as seen by the positive relationship

Fig. 2 Path coefficients for the simple mediation analysis of Model 1–3 with the corresponding regression equations. *Note.* For the dotted path representing the indirect effect *ab,* the 95% bootstrap confidence interval is indicated. *c* represents the total effect according to the regression equation $Y = i_Y + cX + e_Y$. To improve readability, control variables (depressive symptoms, symptoms of social interaction anxiety, mobility, social network size, age, and gender) are not shown in the figure. $N = 436$
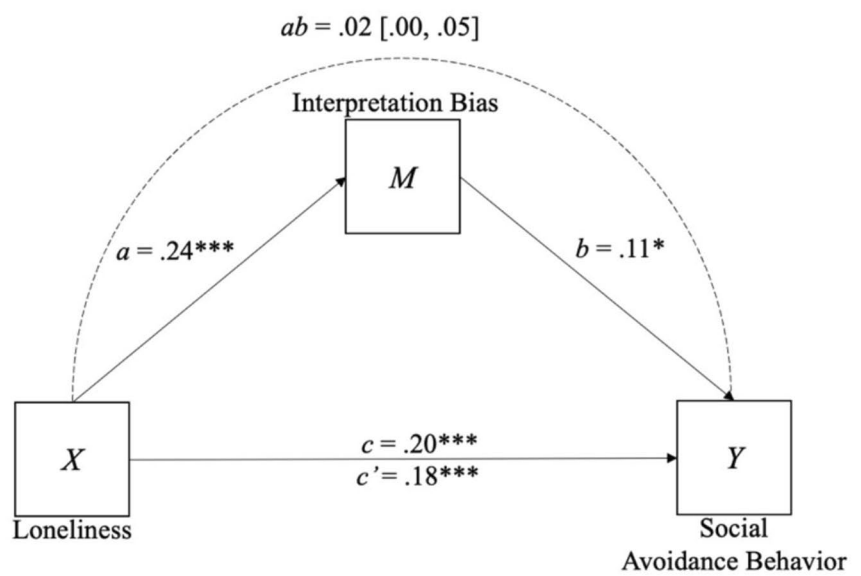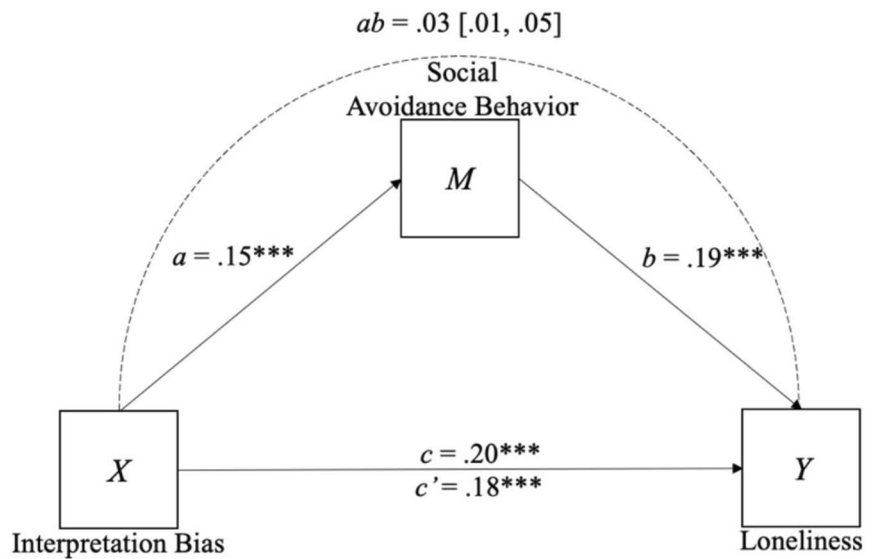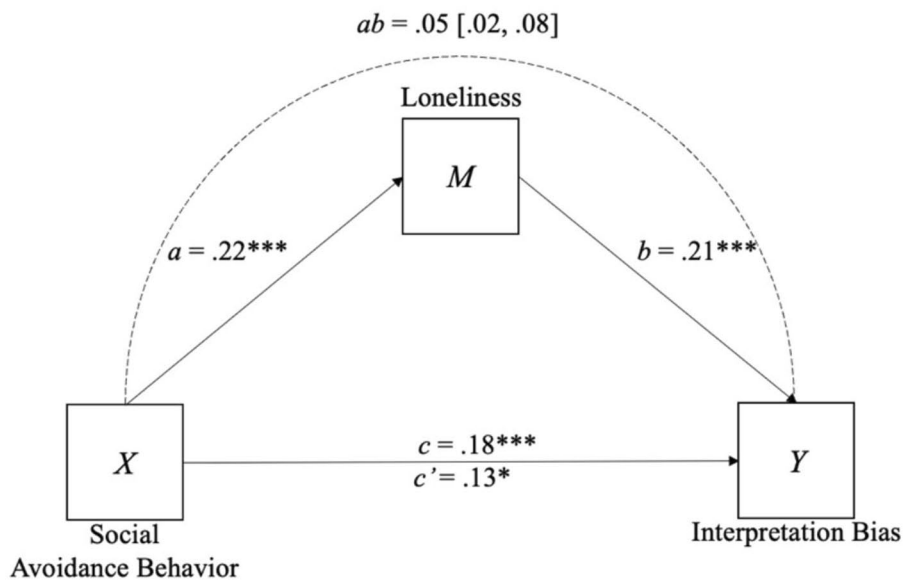
Fig. 3 Visual representation: Moderation of the effect of loneliness on interpretation bias by self-esteem. *Note.* Regression lines for the relationship between loneliness and interpretation bias (standardized) at low levels $(M - SD)$, average levels (M), and high levels of self-esteem $(M + SD)$. $N = 436$
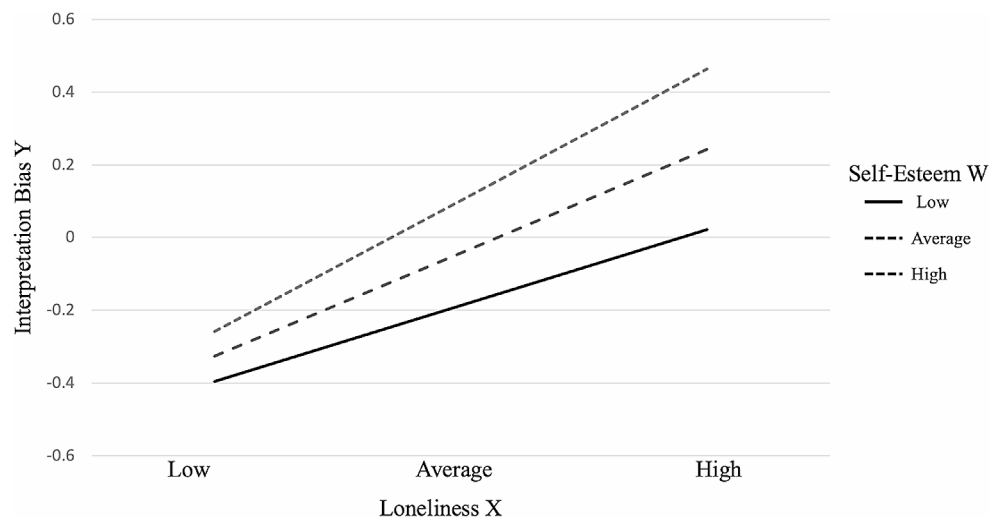
between interpretation bias in social situations and social avoidance behavior. The effect of biased social-cognitive processing exhibits its effect on promoting further feelings of loneliness through these behavioral consequences and aligns with the conclusion that "lonely individuals may view themselves to be passive victims in their social world, but they are active contributors through their self-protective and paradoxically self-defeating interactions with others" (Cacioppo & Hawkley, 2009). Ultimately, our findings showed that the behavioral pattern of lonely individuals, in turn, is likely to promote further biases in social cognition mediated by loneliness.

In sum, the results support the theorized relationship between affective, cognitive, and behavioral components proposed by current models of loneliness (Cacioppo & Hawkley, 2009; Qualter et al., 2015; Spithoven et al., 2017). However, the present study did not examine the longitudinal effects with repeated measures over multiple time points of those three components. The regulatory loop hypothesis posits that the effects of these components are likely to manifest over time. Only a few studies have examined those components in a longitudinal design and found no clear evidence for reciprocal effects over time (Lau et al., 2021; van Winkel et al., 2017). Further research needs to address the interaction between the components of the regulatory loop over time and shed light on the mechanisms behind the development of prolonged loneliness.
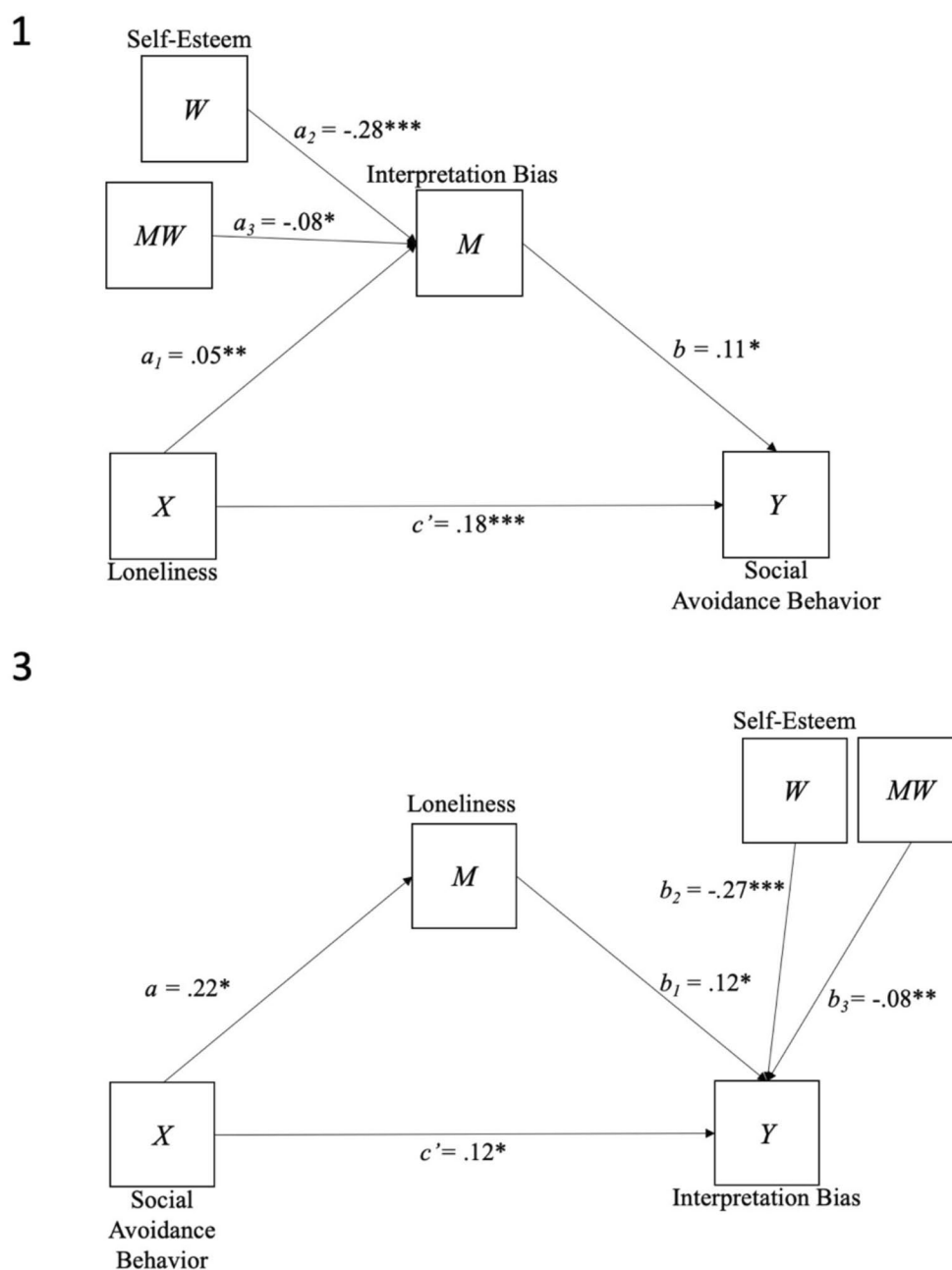
Potential buffering role of self-esteem

This study proposed higher levels of self-esteem as a potential buffer of the effect of loneliness on interpretation bias in social situations. As hypothesized, this relationship depended on a person's self-esteem, where higher levels lessened the effects of loneliness on interpretation bias in social situations. The results support and broaden previous

research, where high self-esteem had a buffering effect not only on loneliness but also on the effects of loneliness on other constructs (Çivitci & Çivitci, 2009; Kong & You, 2013; Rossi et al., 2020). Yet the results have also shown increased moderating effects of lower levels of self-esteem on the relationship between loneliness and interpretation bias, pointing towards the fact that loneliness evokes different reactions to perceived social rejection depending on self-esteem: Low self-esteem goes hand in hand with an oversensitivity to threats in the relational domain (Leary et al., 1998). Combining these insights with the findings on increased reactivity to social rejection cues (Ford & Collins, 2013), the experience of loneliness may initially be quite stressful regardless of the level of self-esteem. However, individuals seem to process social rejection cues differently depending on their level of self-esteem (Kashdan et al., 2014). Moreover, individuals with low self-esteem recover more slowly from perceived daily rejection situations regarding mental and physical health outcomes, potentially leading to cumulative effects with greater health risks in the longer term (Ford & Collins, 2013). Given that perceived social rejection is a fundamental aspect of loneliness, it is reasonable to suggest that high self-esteem might serve as a protective factor against prolonged loneliness, thereby fostering the evolutionary adaptive function of this emotional state (Qualter et al., 2015). Additionally, it must be considered that low self-esteem seems to be a risk factor for the development and perpetuation of loneliness as well (Geukens et al., 2022).

Even though the results of the conditional indirect effects are inconclusive, self-esteem seems to have both a buffering and intensifying effect in the mediation models. These results cautiously point towards the view of Qualter et al. (2015) and Spithoven et al. (2017) regarding the regulatory loop's cognitive part as the pivotal point of prolonged loneliness, where protective factors such as self-esteem can

Fig. 4 Path coefficients for the conditional process analyses of Model 1 & 3 with the corresponding regression equations. *Note.* To improve readability, control variables (depressive symptoms, symptoms of social interaction anxiety, mobility, social network size, age, and gender) are not shown in the Figure. MW = the interaction of loneliness and self-esteem

Implications

As already elaborated, loneliness has been linked to increased mortality and impaired physical and mental health (Hawkley & Capitanio, 2015; Holt-Lunstad et al., 2015; Lau et al., 2021; Rico-Uribe et al., 2018), which leads to the conclusion that the need for interventions seems to be evident. It

be crucial in determining which path an individual follows after experiencing loneliness: the adaptive one, promoting social reconnection, or the one leading into a cycle of negative reinforcement.

is well known that increasing the number of social contacts alone does not necessarily address the cognitive and affective factors that can perpetuate loneliness (Käll et al., 2020). Recent meta-analyses have shown that interventions aimed at reducing loneliness are most effective when maladaptive social cognitions (e.g., interpretation biases in social situations) and social avoidance behavior are targeted (Masi et al., 2011; Zagic et al., 2022). The findings of the present study support the idea that socio-cognitive processes play a pivotal role in the perpetuation of loneliness. Consequently, interventions should prioritize addressing these processes to combat and alleviate loneliness effectively.

Furthermore, the present results suggest that loneliness interventions might profit from an additional focus on self-esteem, which could theoretically promote the reaffiliation motive and potentially reduce loneliness. Equally to loneliness, cognitive behavior therapy seems to be an effective intervention for increasing self-esteem (Niveau et al., 2021). Therefore, it might be beneficial if interventions tackle loneliness and boost self-esteem simultaneously with a cognitive behavioral approach. However, more studies are needed to evaluate different approaches to interventions addressing loneliness since many current studies have primarily focused on cognitive behavioral therapy and social interventions like social skills training or the enhancement of social support (Masi et al., 2011).

Limitations

Some critical limitations in the current study need to be addressed. First, since the models tested were based on cross-sectional data only, no causality can be attributed to the reported pathways. Thus, the data needs to be interpreted with caution and caveats. Nonetheless, cross-sectional data does not impede the application of the methods used in this study (Hayes, 2018). Under these circumstances, the results cannot be seen as evidence for the circular relationship but rather as a preliminary indicator that the models are worth exploring in more detail and with longitudinal data to determine temporal associations. Nevertheless, the incorporation of several constructs previously associated with loneliness as covariates provides further support for the results. Second, the probing of non-significant conditional indirect effects can be done as such, but the results must be interpreted cautiously (Hayes, 2015). Third, the sample cannot be seen as representative of the general public in German-speaking countries, mainly due to the predominantly female, highly educated participants. The age distribution is also not normally distributed and consists mostly of younger participants. A further limitation is that we did not assess ethnicity in the sample. We primarily aimed for a big enough sample size for the analyses regarding the power without considering the representativeness. Lastly, the loneliness model presented here considerably simplifies the actual occurrences surrounding such a phenomenon. The measures used to assess social-cognitive biases (interpretation bias in social situations) and social behavior changes (social avoidance behavior) cannot depict these areas' entire width since they only cover particular aspects of these complex constructs.

Conclusion

This study examined the affective, cognitive, and behavioral aspects of the proposed model of chronic loneliness by Cacioppo and Hawkley (2009) and the effect of self-esteem as a buffer. Our results may provide preliminary empirical support for the central relationships depicted in the regulatory loop, which includes loneliness, interpretation bias in social situations, and social avoidance behavior. Furthermore, self-esteem moderated the effects of loneliness on interpretation bias. The present study's findings support the idea that socio-cognitive processes are pivotal in perpetuating loneliness. Consequently, interventions should address these processes to combat and alleviate loneliness effectively. Furthermore, they may also profit from additionally focusing on self-esteem to potentially promote the motive to reaffiliate. Future research should adopt longitudinal designs to further explore and corroborate the present findings over time.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate This study was approved by the ethics committee of the Faculty of Human Sciences of the University of Bern (2020–08-00005). The participants gave their informed consent at the beginning of the study.

Consent for publication Not applicable.

Competing interests The authors declare that they have no competing interests.

References

Barreto, M., Victor, C., Hammond, C., Eccles, A., Richins, M. T., & Qualter, P. (2021). Loneliness around the world: Age, gender, and cultural differences in loneliness. *Personality and Individual Differences*, *169*, 110066. https://doi.org/10.1016/j.paid.2020.110066

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*, 497–529.

Baumeister, R. F., Campbell, J. D., Krueger, J. I., & Vohs, K. D. (2003). Does High Self-Esteem Cause Better Performance, Interpersonal Success, Happiness, or Healthier Lifestyles? *Psychological Science in the Public Interest*, *4*(1), 1–44. https://doi.org/10.1111/1529-1006.01431

Berkman, L. F., & Syme, S. L. (1979). Social networks, host resistance, and mortality: A nine-year follow-up study of Alameda county residents. *American Journal of Epidemiology*, *109*(2), 186–204. https://doi.org/10.1093/oxfordjournals.aje.a112674

Brettschneider, M., Neumann, P., Berger, T., Renneberg, B., & Boettcher, J. (2015). Internet-based interpretation bias modification for social anxiety: A pilot study. *Journal of Behavior Therapy and Experimental Psychiatry*, *49*(Pt A), 21–29. https://doi.org/10.1016/j.jbtep.2015.04.008

Bührlen, B., Gerdes, N., & Jäckel, W. H. (2005). Entwicklung und psychometrische Testung eines Patientenfragebogens für die medizinische rehabilitation (IRES-3) [Development and psychometric testing of a patient questionnaire for medical rehabilitation (IRES-3)]. *Rehabilitation (Stuttg)*, *44*(02), 63–74. https://doi.org/10.1055/s-2004-834687

Cacioppo, J. T., & Hawkley, L. C. (2009). Perceived social isolation and cognition. *Trends in Cognitive Sciences*, *13*(10), 447–454. https://doi.org/10.1016/j.tics.2009.06.005

Cacioppo, J. T., Fowler, J. H., & Christakis, N. A. (2009). Alone in the crowd: The structure and spread of loneliness in a large social network. *Journal of Personality and Social Psychology*, *97*(6), 977. https://doi.org/10.1037/a0016076

Cacioppo, J. T., Cacioppo, S., & Boomsma, D. I. (2014). Evolutionary mechanisms for loneliness. *Cognition & Emotion*, *28*(1), 3–21. https://doi.org/10.1080/02699931.2013.837379

Çivitci, N., & Çivitci, A. (2009). Self-esteem as mediator and moderator of the relationship between loneliness and life satisfaction in adolescents. *Personality and Individual Differences*, *47*(8), 954–958. https://doi.org/10.1016/j.paid.2009.07.022

Cohen-Mansfield, J., & Parpura-Gill, A. (2007). Loneliness in older persons: A theoretical model and empirical findings. *International Psychogeriatrics*, *19*(2), 279–294. https://doi.org/10.1017/S1041610206004200

Cornwell, E. Y., & Waite, L. J. (2009). Social disconnectedness, perceived isolation, and health among older adults. *Journal of Health and Social Behavior*, *50*(1), 31–48. https://doi.org/10.1177/002214650905000103

Danneel, S., Geukens, F., Maes, M., Bastin, M., Bijttebier, P., Colpin, H., Verschueren, K., & Goossens, L. (2020). Loneliness, social anxiety symptoms, and depressive symptoms in adolescence: Longitudinal distinctiveness and correlated change. *Journal of Youth and Adolescence*, *49*(11), 2246–2264. https://doi.org/10.1007/s10964-020-01315-w

Döring, N., & Bortz, J. (1993). Psychometrische Einsamkeitsforschung: Deutsche Neukonstruktion der UCLA loneliness scale. [Psychometric research on loneliness: A new German version of the University of California at Los Angeles (UCLA) loneliness scale.]. *Diagnostica*, *39*, 224–239.

Ford, M. B., & Collins, N. L. (2010). Self-esteem moderates neuroendocrine and psychological responses to interpersonal rejection. *Journal of Personality and Social Psychology*, *98*, 405–419. https://doi.org/10.1037/a0017345

Ford, M. B., & Collins, N. L. (2013). Self-esteem moderates the effects of daily rejection on health and well-being. *Self and Identity*, *12*(1), 16–38. https://doi.org/10.1080/15298868.2011.625647

Geukens, F., Maes, M., Spithoven, A., Pouwels, J. L., Danneel, S., Cillessen, A. H. N., van den Berg, Y. H. M., & Goossens, L. (2022). Changes in adolescent loneliness and concomitant changes in fear of negative evaluation and self-esteem. *International Journal of Behavioral Development*, *46*(1), 10–17. https://doi.org/10.1177/0165025420958194

Gyurak, A., & Ayduk, Ö. (2007). Defensive physiological reactions to rejection: The effect of self-esteem and attentional control on startle responses. *Psychological Science*, *18*(10), 886–892. https://doi.org/10.1111/j.1467-9280.2007.01996.x

Härtel, U., Stieber, J., & Keil, U. (1988). Social relations and smoking behavior: Results from the first MONICA survey Augsburg. *Sozial- Und Präventivmedizin/social and Preventive Medicine*, *33*(1), 27–31. https://doi.org/10.1007/BF02084002

Hawkley, L. C., & Capitanio, J. P. (2015). Perceived social isolation, evolutionary fitness and health outcomes: A lifespan approach. *Philosophical Transactions of the Royal Society b: Biological Sciences*, *370*(1669), 20140114. https://doi.org/10.1098/rstb.2014.0114

Hayes, A. F. (2015). An index and test of linear moderated mediation. *Multivariate Behavioral Research*, *50*(1), 1–22. https://doi.org/10.1080/00273171.2014.962683

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). Guilford publications.

Heinrich, L. M., & Gullone, E. (2006). The clinical significance of loneliness: A literature review. *Clinical Psychology Review*, *26*(6), 695–718. https://doi.org/10.1016/j.cpr.2006.04.002

Holt-Lunstad, J., Smith, T. B., Baker, M., Harris, T., & Stephenson, D. (2015). Loneliness and social isolation as risk factors for mortality: A meta-analytic review. *Perspectives on Psychological Science*, *10*(2), 227–237. https://doi.org/10.1177/1745691614568352

IBM Corp. (2021). *IBM SPSS Statistics for Macintosh*. In (Version 28.0). https://www.ibm.com

Käll, A., Shafran, R., Lindegaard, T., Bennett, S., Cooper, Z., Coughtrey, A., & Andersson, G. (2020). A common elements approach to the development of a modular cognitive behavioral theory for chronic loneliness. *Journal of Consulting and Clinical Psychology*, *88*(3), 269–282. https://doi.org/10.1037/ccp0000454

Kashdan, T. B., DeWall, C. N., Masten, C. L., Pond, R. S., Jr., Powell, C., Combs, D., Schurtz, D. R., & Farmer, A. S. (2014). Who is most vulnerable to social rejection? The toxic combination of low self-esteem and lack of negative emotion differentiation on neural responses to rejection. *PLoS ONE*, *9*(3), e90651. https://doi.org/10.1371/journal.pone.0090651

Kong, F., & You, X. (2013). Loneliness and self-esteem as mediators between social support and life satisfaction in late adolescence. *Social Indicators Research*, *110*(1), 271–279. https://doi.org/10.1007/s11205-011-9930-6

Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine*, *16*(9), 606–613.

Lau, J. F., Shariff, R., & Meehan, A. (2021). Are biased interpretations of ambiguous social and non-social situations a precursor, consequence or maintenance factor of youth loneliness? *Behaviour Research and Therapy*, *140*, 103829. https://doi.org/10.1016/j.brat.2021.103829

Leary, M. R., Haupt, A. L., Strausser, K. S., & Chokel, J. T. (1998). Calibrating the sociometer: The relationship between interpersonal appraisals and the state self-esteem. *Journal of Personality and Social Psychology*, *74*, 1290–1299. https://doi.org/10.1037/0022-3514.74.5.1290

Lim, M., Qualter, P., Ding, D., Holt-Lunstad, J., Mikton, C., & Smith, B. (2023). Advancing loneliness and social isolation as global health priority: taking three priority actions. *Public Health Research & Practice*, *33*(3), e3332320. https://doi.org/10.17061/phrp3332320

Löwe, B., Kroenke, K., Herzog, W., & Gräfe, K. (2004). Measuring depression outcome with a brief self-report instrument: Sensitivity to change of the Patient Health Questionnaire (PHQ-9). *Journal of Affective Disorders*, *81*(1), 61–66. https://doi.org/10.1016/S0165-0327(03)00198-8

Luhmann, M., Bohn, J., Holtmann, J., Koch, T., & Eid, M. (2016). I'm lonely, can't you tell? Convergent validity of self- and informant ratings of loneliness. *Journal of Research in Personality*, *61*, 50–60. https://doi.org/10.1016/j.jrp.2016.02.002

Luhmann, M., Buecker, S., & Rüsberg, M. (2023). Loneliness across time and space. *Nature Reviews Psychology*, *2*(1), 9–23. https://doi.org/10.1038/s44159-022-00124-1

Maes, M., Nelemans, S. A., Danneel, S., Fernandez-Castilla, B., Van den Noortgate, W., Goossens, L., & Vanhalst, J. (2019a). Loneliness and social anxiety across childhood and adolescence: Multilevel meta-analyses of cross-sectional and longitudinal associations. *Developmental Psychology*, *55*(7), 1548–1565. https://doi.org/10.1037/dev0000719

Maes, M., Qualter, P., Vanhalst, J., Van den Noortgate, W., & Goossens, L. (2019b). Gender differences in loneliness across the lifespan: A meta-analysis. *European Journal of Personality*, *33*(6), 642–654. https://doi.org/10.1002/per.2220

Masi, C. M., Chen, H.-Y., Hawkley, L. C., & Cacioppo, J. T. (2011). A meta-analysis of interventions to reduce loneliness. *Personality and Social Psychology Review*, *15*(3), 219–266. https://doi.org/10.1177/1088868310377394

Niveau, N., New, B., & Beaudoin, M. (2021). Self-esteem interventions in adults– A systematic review and meta-analysis. *Journal of Research in Personality*, *94*, 104131. https://doi.org/10.1016/j.jrp.2021.104131

Okruszek, Ł, Piejka, A., Krawczyk, M., Schudy, A., Wiśniewska, M., Żurek, K., & Pinkham, A. (2021). Owner of a lonely mind? Social cognitive capacity is associated with objective, but not perceived social isolation in healthy individuals. *Journal of Research in Personality*, *93*, 104103. https://doi.org/10.1016/j.jrp.2021.104103

Orth, U., & Robins, R. W. (2014). The development of self-esteem. *Current Directions in Psychological Science*, *23*(5), 381–387. https://doi.org/10.1177/0963721414547414

Ottenbreit, N. D., & Dobson, K. S. (2004). Avoidance and depression: The construction of the cognitive-behavioral avoidance scale. *Behaviour Research and Therapy*, *42*(3), 293–313. https://doi.org/10.1016/s0005-7967(03)00140-2

Peplau, L. A., & Perlman, D. (1979). Blueprint for a social psychological theory of loneliness. In M. Cook & G. Wilson (Eds.), *Love and attraction: An Interpersonal Conference* (pp. 101–110). Pergamon Press. https://doi.org/10.1016/b978-0-08-022234-9.50020-0

Peplau, L. A., & Perlman, D. (1982). Perspective on loneliness. In L. A. Peplau & D. Perlman (Eds.), *Loneliness: A sourcebook of current theory, research and therapy* (pp. 1–18). Wiley.

Peters, L., Sunderland, M., Andrews, G., Rapee, R. M., & Mattick, R. P. (2012). Development of a short form Social Interaction Anxiety (SIAS) and Social Phobia Scale (SPS) using nonparametric item response theory: The SIAS-6 and the SPS-6. *Psychological Assessment*, *24*(1), 66–76. https://doi.org/10.1037/a0024544

Qualter, P., Rotenberg, K., Barrett, L., Henzi, P., Barlow, A., Stylianou, M., & Harris, R. A. (2013). Investigating hypervigilance for social threat of lonely children. *Journal of Abnormal Child Psychology*, *41*(2), 325–338. https://doi.org/10.1007/s10802-012-9676-x

Qualter, P., Vanhalst, J., Harris, R., Van Roekel, E., Lodder, G., Bangee, M., Maes, M., & Verhagen, M. (2015). Loneliness across the life span. *Perspectives on Psychological Science*, *10*(2), 250–264. https://doi.org/10.1177/1745691615568999

R Core Team. (2022). *R: a language and environment for statistical computing*. In (Version 4.2.1). https://www.R-project.org/

Rico-Uribe, L. A., Caballero, F. F., Martín-María, N., Cabello, M., Ayuso-Mateos, J. L., & Miret, M. (2018). Association of loneliness with all-cause mortality: A meta-analysis. *PLoS ONE*, *13*(1), e0190033. https://doi.org/10.1371/journal.pone.0190033

Rokach, A. (1988). The experience of loneliness: A tri-level model. *The Journal of Psychology*, *122*(6), 531–544. https://doi.org/10.1080/00223980.1988.9915528

Rosenberg, M., Schooler, C., & Schoenbach, C. (1989). Self-esteem and adolescent problems: Modeling reciprocal effects. *American Sociological Review*, *54*(6), 1004–1018. https://doi.org/10.2307/2095720

Rossi, A., Panzeri, A., Pietrabissa, G., Manzoni, G. M., Castelnuovo, G., & Mannarini, S. (2020). The anxiety-buffer hypothesis in the time of COVID-19: When self-esteem protects from the impact of loneliness and fear on anxiety and depression [Original Research]. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.02177

Röthlin, P., Grosse Holtforth, M., Bergomi, C., Berking, M., Ottenbreit, N. D., & Caspar, F. (2010). Vermeidung und depression. *Diagnostica*, *56*(1), 46–55. https://doi.org/10.1026/0012-1924/a000008

Russell, D. W. (1996). UCLA loneliness scale (version 3): Reliability, validity, and factor structure. *Journal of Personality Assessment*, *66*(1), 20–40. https://doi.org/10.1207/s15327752jpa6601_2

Santini, Z. I., Jose, P. E., York Cornwell, E., Koyanagi, A., Nielsen, L., Hinrichsen, C., Meilstrup, C., Madsen, K. R., & Koushede, V. (2020). Social disconnectedness, perceived isolation, and symptoms of depression and anxiety among older Americans (NSHAP): A longitudinal mediation analysis. *The Lancet Public Health*, *5*(1), e62–e70. https://doi.org/10.1016/s2468-2667(19)30230-0

Spithoven, A. W. M., Bijttebier, P., & Goossens, L. (2017). It is all in their mind: A review on information processing bias in lonely individuals. *Clinical Psychology Review*, *58*, 97–114. https://doi.org/10.1016/j.cpr.2017.10.003

Ti, Y., Wei, J., & Hao, Z. (2022). The longitudinal association between loneliness and self-esteem among Chinese college freshmen. *Personality and Individual Differences*, *193*, 111613. https://doi.org/10.1016/j.paid.2022.111613

van Winkel, M., Wichers, M., Collip, D., Jacobs, N., Derom, C., Thiery, E., Myin-Germeys, I., & Peeters, F. (2017). Unraveling the role of loneliness in depression: The relationship between daily life experience and behavior. *Psychiatry*, *80*(2), 104–117. https://doi.org/10.1080/00332747.2016.1256143

Vanhalst, J., Luyckx, K., Raes, F., & Goossens, L. (2012). Loneliness and depressive symptoms: The mediating and moderating role of uncontrollable ruminative thoughts. *The Journal of Psychology*,

146(1–2), 259–276. https://doi.org/10.1080/00223980.2011.555433

von Collani, G., & Herzberg, P. Y. (2003). Eine revidierte Fassung der deutschsprachigen Skala zum Selbstwetgefühl von Rosenberg. [A revised version of the German adaptation of Rosenberg's Self-Esteem Scale.]. *Zeitschrift Für Differentielle Und Diagnostische Psychologie*, *24*, 3–7. https://doi.org/10.1024/0170-1789.24.1.3

Voncken, M. J., Bögels, S. M., & Peeters, F. (2007). Specificity of interpretation and judgemental biases in social phobia versus depression. *Psychology and Psychotherapy: Theory, Research and Practice*, *80*(3), 443–453. https://doi.org/10.1348/147608306X161890

Wirtz, M., Farin, E., Bengel, J., Jäckel, W. H., Hämmerer, D., & Gerdes, N. (2005). IRES-24 Patientenfragebogen. *Diagnostica*, *51*(2), 75–87. https://doi.org/10.1026/0012-1924.51.2.75

Zagic, D., Wuthrich, V. M., Rapee, R. M., & Wolters, N. (2022). Interventions to improve social connections: A systematic review and meta-analysis. *Social Psychiatry and Psychiatric Epidemiology*, *57*(5), 885–906. https://doi.org/10.1007/s00127-021-02191-w