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Associations of State and Chronic Loneliness with Interpretation Bias: The Role of Internalizing Symptoms

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Abstract

Loneliness is common and, while generally transient, persists in up to 22% of the population. The rising prevalence and adverse impacts of chronic loneliness highlight the need to understand its underlying mechanisms. Evolutionary models of loneliness suggest that chronically lonely individuals demonstrate negative interpretation biases towards social information. It may also be that such biases are exacerbated by momentary increases in state loneliness, or elevated anxiety or depression. Yet, little research has tested these possibilities. The current study aimed to advance understandings of loneliness by examining associations of chronic loneliness with individual differences in negative interpretation bias for social (relative to non-social) stimuli, and testing whether these associations change in the context of increased state loneliness and current levels of anxiety and depressive symptoms. These aims were explored in 591 participants who completed an interpretation bias task before and after undergoing a state loneliness induction. Participants also self-reported chronic loneliness, anxiety, and depression. Linear mixed models indicated that only state (but not chronic) loneliness was associated with more positive interpretations of non-social stimuli, with greater anxiety and depressive symptoms predicting more negative interpretations. Implications of these findings for present theoretical models of loneliness are discussed.

Keywords: Interpretation bias, loneliness, depression, anxiety

Associations of State and Chronic Loneliness with Interpretation Bias: The Role of Internalizing Symptoms

Loneliness is a negative emotional state arising from a discrepancy between one's desired and actual social relationships (Hawkley & Cacioppo, 2010). Though normative and generally transient, elevated levels of loneliness persist in up to 22% of the population (Qualter et al., 2013a; Qualter et al., 2015). Chronically lonely individuals are vulnerable to adverse mental and physical health outcomes, ranging from significantly increased risk for depression (Cacioppo et al., 2006) to cardiovascular disease (Thurston & Kubzansky, 2009). These deleterious outcomes demonstrate the critical need to understand mechanisms underlying chronic loneliness, as differentiated from transient or state loneliness.

The evolutionary theory of loneliness is among the most prominent explanatory models of this construct (Cacioppo et al., 2014; Cacioppo & Hawkley, 2009; Hawkley & Cacioppo, 2010). This theory conceptualizes loneliness as a biological alarm signalling threat to one's social connections. Specifically, given the evolutionary dangers of living alone, lonely individuals are putatively hypervigilant to social threats in their environment, manifesting as negative cognitive biases for social information. Though adaptive in some contexts, this social negativity bias may help to perpetuate perceived isolation by eliciting negative perceptions of social relationships and avoidance of interactions (i.e., social withdrawal), creating a feedback loop of chronic loneliness. Thus, a body of work has examined the link between chronic loneliness and negative interpretation bias to better understand its underlying cognitive mechanisms.

Much of this work has examined how chronically lonely individuals interpret others' intent in ambiguous social scenarios, otherwise known as attribution bias (Spithoven et al.,

2017). For example, several studies link greater chronic loneliness with more hostile attributions of ambiguous social situations (Okruszek et al., 2021; Qualter et al., 2013b). Yet, only one study tested the specificity of this bias for social information (Lau et al., 2021). To examine associations between chronic loneliness and threatening interpretations of social and non-social scenarios, participants read written vignettes and rated the likelihood of threatening (relative to benign) outcomes. More chronically lonely individuals demonstrated a more negative bias irrespective of scenario type, possibly evidencing a more generalized heightened threat processing in chronic loneliness. Of note, however, such findings have been demonstrated using "offline" tasks (e.g., self-report questionnaires) which give participants time to reflect on ambiguous information before providing interpretations in a relatively controlled manner (Hirsch et al., 2016). Such tasks may be more vulnerable to influence from demand effects or selection bias, as participants select from a range of interpretations provided versus the first that comes to mind. Thus, it remains unclear whether these same associations would be observed if using tasks that prioritize more covert or "online" methods equipped to capture the often involuntary, automatic process through which interpretations are formed in the real world.

In this regard, it may be especially critical to measure interpretations of the visual ambiguity that subsumes much of our daily lives, as is captured by the valence bias task (Neta & Brock, 2021; Harp & Neta, 2023). Here, participants rapidly categorize a series of ambiguous images as either positive or negative. A distinct advantages of this task is that it can be used to examine whether biases in chronic loneliness are not only socially specific (i.e., by allowing for categorization of images by social content) but also modulated by momentary changes in state affect. Indeed, there is reason to believe that the negativity bias inherent to chronic loneliness may be triggered or exacerbated by transient increases in state loneliness (Harp & Neta, 2023;

Qualter et al., 2015). Moreover, individual differences in mood- or stress-induced changes in emotional processing have been demonstrated using the valence bias task (Raio et al., 2021), suggesting it may also evince changes during state loneliness. Testing whether this is the case might inform understanding of how chronically lonely individuals cognitively respond to normative changes in state loneliness in daily life. Whereas some individuals might be less impacted by these transient feelings, those high in chronic loneliness could be especially vulnerable to changes in state loneliness and cognitive processing which put them at risk for further emotional sequelae.

Also relevant are the roles of internalizing symptoms in the link between chronic loneliness and negativity bias. Indeed, meta-analytic studies have demonstrated moderate to strong associations of generalized anxiety and depression with negative interpretation biases (Stuijfzand et al., 2017; Everaert et al., 2017). In anxiety, this tendency has been posited as reflecting a non-specific hypersensitivity to both social and non-social threatening information (Hirsch et al., 2016; Park et al., 2016). Negative beliefs about the self, future, and others have also been implicated in the tendency to infer more negative interpretations of ambiguity in depression (Everaert, 2021; LeMoult & Gotlib, 2019). Given that chronically lonely individuals tend to report heightened levels of depression and anxiety (Cacioppo et al., 2006; Santini et al., 2020), it may be especially important to examine how these symptoms and their underlying cognitive mechanisms overlap with those observed in chronic loneliness. For example, it may be that internalizing symptoms heighten threat processing in chronic loneliness, thereby exacerbating its associated negativity bias. While suggesting a possible moderation effect, little work has considered the role of internalizing symptoms in associations between chronic loneliness and negative interpretation bias.

In this pre-registered study (https://aspredicted.org/BCJ_68F), we examined associations of chronic loneliness with individual differences in negative interpretation bias for social (relative to non-social) ambiguity, and changes in these associations according to increased state loneliness and current levels of anxiety and depressive symptoms. Although no consensus yet exists regarding what constitutes chronic loneliness, we define it here in terms of persistence, which (as recently argued by Qualter et al., 2021) is captured by the UCLA Loneliness Scale (Russell, 1996). Correspondingly, undergraduate participants with varying levels of chronic loneliness completed an online task assessing visual interpretation bias (i.e., valence bias task; Neta & Brock, 2021). They next underwent a state loneliness induction (Roddick & Chen, 2021) before completing the valence bias task a second time. Participants also self-reported generalized anxiety and depression symptoms. Based on extant theoretical models and preliminary empirical findings (Cacioppo & Hawkley, 2010; Harp & Neta, 2023; Qualter et al., 2015), we hypothesized that chronic loneliness would be associated with more negative interpretation biases for social information (hypothesis 1), particularly during momentary increases in state loneliness (hypothesis 2) or among those with elevated anxiety and/or depressive symptomology (hypothesis 3).

Methods

Participants

Participants included undergraduate students recruited from the University of British Columbia Human Subject Pool (HSP). Eligible participants were over 18 years old and fluent in English. All participants received course credit following completion of the study. Of the 805 participants who consented to participate in the study, 761 went on to attempt the pre-test valence bias task. Of these, 46 were excluded from analyses for hypotheses 1 and 3 for providing

poor quality valence bias data (see measures section). Of the remaining 715 participants, 666 completed the study questionnaires, with 75 removed for providing invalid data (n = 7 withdrew consent; n = 41 failed more than one out of three attention checks; n = 27 rated as less than four out of seven their attention during the study and/or confidence in their data; n = 1 reported their age as being less than 18 years old). This left a total sample of 591 participants with valid valence bias pre-test and questionnaire data. Participants were between 18 and 53 years old (M = 20.50, SD = 3.70), with approximately 73% identifying as women (additional participant characteristics described in Table 1). For hypothesis 2, 580 participants attempted the state loneliness induction, with 11 participants excluded for engaging with the induction incorrectly (n = 5 took longer than two SDs above the mean to complete the task; n = 6 failed the manipulation check), leaving 569 participants. Of the 568 who attempted the valence bias task at post-test, an additional 68 were excluded for providing invalid data on the interpretation bias task (see measures section), leaving a total sample of 500 to be included in analyses for hypothesis 2.

Measures

Interpretation Bias

Procedure. To assess interpretation biases for social and non-social information, participants completed a modified version of the Valence Bias Task (Neta & Brock, 2021) before and after the loneliness induction. Here, participants categorized as positive or negative images that varied by valence (i.e., ambiguous, clearly valenced [positive, negative]) and social relevance (i.e., social, non-social). Before beginning the task, participants received instructions to rate the valence of each image based on their "gut feeling." Each trial began with a white fixation cross for 1500 ms, followed by an image presented on a black background for 500 ms (see Figure 1; Neta & Brock, 2021). Participants then made positive or negative ratings by

pressing “A” or “L” on their keyboard (key pairing randomized across participants). If participants did not make a response within 2000 ms, the task advanced to the next trial with no response recorded. Clearly valenced and ambiguous social and non-social images were presented in a random order across participants.

Valence bias was quantified as the percent negative ratings, or the percentage of trials on which a participant categorized an emotionally ambiguous stimulus as negative out of the total number of trials for that condition (Neta & Brock, 2021). Separate indices were calculated for ratings of social and non-social images. Clearly valenced stimuli were included as a measure of accuracy; participants who failed to provide accurate ratings of clearly valenced scenes on at least 60% of the trials (n_{pre} = 9; n_{post} = 58) were excluded from analyses, consistent with prior work (e.g., Neta et al., 2009; 2013; 2018; Brown et al., 2017). Reaction times were also used as a measure of data quality; trials with reaction times 3 *SD*s above the group mean (n_{pre} = 2949 [4.05%], n_{post} = 3091 [4.53%]) or less than 250 ms (n_{pre} = 1165 [1.60%], n_{post} = 2200 [3.22%]) were removed before data-analysis, with the latter representing a lower threshold for simple reaction time tasks (e.g., pressing a key upon attending to a stimulus; Posner, 1980) that is implausible for more complex, valence discrimination tasks (Harp et al., 2021). As in prior work (Harp et al., 2021), participants who lost more than 25% of their total trials based on reaction time or non-responses (n_{pre} = 37, n_{post} = 10) were removed from analyses. All other participants lost no more than 24 trials, with a total of 4114 trials (5.65%) removed from pre-test (*M[SD]* = 2.17 [3.55] per participant) and 5291 trials (7.75%) removed from post-test (*M[SD]* = 2.36 [3.30] per participant). Permutation-based split half reliabilities calculated using the *splithalf* package in R (Parsons, 2021) for pre- and post-induction percent negative ratings were 0.83 and 0.85, respectively.

Stimuli. We used 192 images of scenes that varied by the presence versus absence of social content (i.e., human facial expressions, gestures, and/or body language; p & Lepage, 2013). As in previous versions, images were taken from the International Affective Picture System (IAPS; Lang et al., 1999), in addition to the Open Affective Standardized Image Set (OASIS; Kurdi et al., 2017), Nencki Affective Picture System (NAPS; Marchewka et al., 2014), and Geneva Affective Picture Database (GAPED; Dan-Glauser & Scherer, 2011). As in prior work (Neta et al., 2013), normative ratings for each picture database were used to stratify images by valence. Clearly positive images (e.g., two friends laughing) included those with a mean valence in the top 25% (e.g., ≥ 7 out of 9), while clearly negative images (e.g., a sad child) included those with a mean valence in the lower 25% of each rating scale (e.g., ≤ 3 out of 9). Ambiguous images were those having the highest standard deviation in valence ratings, and a mean valence between 25% to 75% (e.g., between 3-7 out of 9), as in previous work (Neta et al., 2013). After ambiguous images were selected, the mean and standard deviation for arousal ratings for these images were calculated based on normed ratings from each dataset. Consistent with prior research (Harp et al., 2021; Neta et al., 2013), images with an arousal rating one standard deviation above or below this overall mean were eliminated to facilitate matching stimuli on arousal across conditions. Independent sample *t*-tests were used to confirm that image valence properties (i.e., mean, standard deviation) were significantly different between the positive, negative, and ambiguous conditions, and that arousal ratings did not significantly differ across valence conditions. The 192 images were then divided into two sets, such that different images were viewed by participants during the pre- and post-test. Each set contained 48 social (24 clearly valenced, 24 ambiguous) and 48 non-social (24 clearly valenced, 24 ambiguous)

images.[1] Independent sample *t*-tests confirmed that valence ratings and arousal ratings did not differ between social and non-social images (valence: $t(190) = -0.40$, $p = .694$; arousal: $t(190) = 1.16$, $p = .246$), images presented at the pre- and post-test (valence: $t(190) = -0.05$, $p = .965$; arousal: $t(190) = 0.67$, $p = .504$), or the 48 images included in the original stimulus set (Neta & Brock, 2021) relative to the 144 new images selected for use in this study (valence: $t(77) = 0.74$, $p = .465$; arousal: $t(77) = 0.72$, $p = .473$).

State Loneliness Induction

The state loneliness induction was adapted for online use based on the procedure described by Roddick and Chen (2021), who developed a loneliness induction procedure based on a combination of commonly adopted loneliness manipulation techniques. Participants were first informed that they were helping to validate a new "text analysis application" called the Linguistic Analysis and Word Count (LAWC) program by completing an emotional writing task. While fictional, this program is based on the real LIWC2015 (Linguistic Inquiry and Word Count) program developed by Pennebaker et al. (2015). Each participant was told the following:

> The LAWC program is a text analysis application that enables rapid assessment of emotional and cognitive components in verbal and written speech. The LAWC assesses vocabulary, word patterns, and syntax to derive information about individuals' thought patterns, personality characteristics, and social relationships. Although the LAWC has been used effectively in Europe for several years, UBC is part of a Canadian initiative to validate the program with a North American student sample.

[1] One ambiguous non-social image from the pre-test version of the task was duplicated. Duplicate responses to this image were removed prior to final scores being calculated, meaning that pre-test valence bias scores calculated based on responses to 47 (versus 48) stimuli.

Participants then read a set of instructions displayed on the computer screen which prompted them to write about an experience of loneliness. Participants were told to recall and evoke details about the situation, how they felt, and what their thoughts were at the time. Each participant was then given 10 minutes to reflect on and type out their description of a personal loneliness experience into a text box, after which they were prompted to "submit" their sample for analysis. A pre-programmed page then appeared on-screen displaying a "high" loneliness score of 52.98, as well as other information suggesting that the LAWC program identified the participant as higher than average in loneliness. The following additional information was designed to enhance the believability of the false feedback:

> The program should have provided you with a loneliness score between zero and eighty. Higher scores indicate more intrinsic loneliness, and lower scores indicate less intrinsic loneliness. The average loneliness score of a typical undergraduate student at UBC in 2021 was 36.2.

Consistent with Roddick and Chen (2021), participants were then asked to indicate whether their obtained score was *lower*, *higher*, or *equal* to the UBC average. This ensured that participants had read and understood the false feedback provided. As described above, 6 participants who selected the *lower* or *equal* options (i.e., failed the manipulation check) were excluded from study analyses. Next, participants' written responses to the loneliness prompt were displayed on the screen as they were asked to reflect on this experience in light of the "feedback" they received. This reflection period was included to enhance participants' engagement and maximize the emotional impact of the task. At the end of the session, participants also provided feedback on the state loneliness task by answering the items, "How effortful did you find the reflection task?" on a scale from 1 (*not at all*) to 7 (*extremely*) and "How plausible did you feel the

loneliness feedback was?" on a scale from 1 (*not plausible at all*) to 7 (*completely plausible*). On average, participants experienced the task as moderately effortful (M = 4.23, SD = 1.46) and reported the feedback to be reasonably plausible (M = 4.56, SD = 1.56). Ratings were consistent with prior work that administered this task in the laboratory (Roddick & Chen, 2021).

Chronic Loneliness

The UCLA Loneliness Scale (Version 3) was used to measure chronic feelings of loneliness or subjective social isolation (Russell, 1996). This scale contains statements referring to the frequency or persistence of feelings or behaviours that accompany the experience of loneliness (Qualter et al., 2021). On this basis, it is often used to quantify chronic or persistent loneliness and is among the most common measures in the field. Individuals indicated how often they experienced feelings described in each of the 20 statements on a 4-point scale from 1 (*never*) to 4 (*always*). This scale demonstrates strong convergent, discriminant, and construct validity in university students (among other populations; Russell, 1996). Excellent internal reliability was also demonstrated in the present study (α = 0.94). Mean scores (M = 46.28) were slightly greater, although still within the range of scores obtained from previous university student samples (e.g., M = 40.08; Russell, 1996).

State Affect

Participants completed a 10-item measure of state affect, similar to prior research (Roddick & Chen, 2021). Specifically, participants indicated to what extent they felt lonely, tense, sad, worried, bored, angry, hostile, alert, happy, and relaxed on a scale from 0 (*not at all*) to 10 (*extremely*). This measure was completed at four separate time points: immediately before and after the first valence bias task, after the 15-minute state loneliness manipulation, and after completion of the second valence bias task and study questionnaires. These questions are based

on the Positive and Negative Affect Schedule, which demonstrates strong reliability and validity across non-clinical populations (Crawford & Henry, 2004). Average internal consistency was good for positive (α = 0.86) and negative affect sub-scales (α = 0.84) across the four time points.

Depression

The Centre for Epidemiological Studies Depression Scale-Revised (CESD-R) was used to capture depressive symptoms (Eaton et al., 2004). This 20-item measure was designed for use in research on the associations between depression and other variables in the general population (Eaton et al., 2004). Respondents reported how frequently they experienced each of the 20 items (e.g., "I felt sad", "I thought my life had been a failure") on a 5-point scale from 0 (*not at all*) to 4 (*nearly every day for two weeks*). This measure has demonstrated strong internal and test-retest reliability, and discriminant and convergent validity across samples (including non-clinical populations; Van Dam & Earleywine, 2011). Excellent internal consistency reliability was also described in the present study (α = 0.92).

Anxiety

The Generalized Anxiety Disorder-7 (GAD-7) was used to measure symptoms of generalized anxiety (Spitzer et al., 2006). This 7-item scale assesses the frequency of anxiety symptoms in the past two weeks. Respondents indicated how often they were bothered by symptoms (e.g., "feeling nervous, anxious, or on edge," "trouble relaxing") on a 4-point scale, from 0 (*not at all*) to 3 (*nearly every day*). This measure demonstrates strong criterion, construct, factorial, and procedural validity, in the general population (Löwe et al., 2008; Spitzer et al., 2006). Excellent internal consistency reliability was also described in the present study (α = 0.92).

Demographics

Participants provided information on their age, gender, ethnicity, yearly household income, relationship status, and education to be analysed descriptively. Consistent with prior work (Harp et al., 2021), gender was also included as a covariate in analyses. However, age was omitted due to its limited range and skewed distribution, with the majority of the sample being between the ages of approximately 18-23 years old.

Procedure

After obtaining approval from the institutional ethics board, data were collected from each participant over the course of a two-hour online session. Participants first provided informed consent and completed a measure of state affect (including state loneliness). Next, they completed the valence bias task (Neta & Brock, 2021). This was followed by a second measure of state affect, after which participants were told that they were taking a break from the image ratings task to complete a second task (i.e., the state loneliness induction). Immediately following the induction, they completed a third measure of state affect to ensure that the manipulation was successful, after which they repeated the valence bias task with previously unseen stimuli. After this task, participants completed a demographic questionnaire, followed by measures of chronic loneliness, state affect, depression, and anxiety. Measures of chronic loneliness, depression, and anxiety were completed after the valence bias task to ensure that answering questions about one's negative mood did not impact valence bias task performance or responses to the loneliness induction. Finally, participants were thoroughly debriefed, which included providing information regarding the false nature of the loneliness feedback and the necessity of this deception for the study. Participants were also given the opportunity to watch videos containing positive stimuli (i.e., baby animals) to alleviate any ongoing negative affect and could contact the researchers with any concerns regarding their participation in the study.

Valence bias data was collected using PsychoPy (Pierce, 2007) and loneliness induction and questionnaire responses were collected using Qualtrics.

Analytic Strategy

Preliminary Analyses

One-way repeated measures analyses of variance (ANOVA) were conducted on self-reported feelings of state loneliness, as well as positive and negative affect, at baseline, pre- and post-induction, and after completion of study questionnaires. Results of these analyses were intended to support the effectiveness of the induction at inducing changes in loneliness, specifically, as well as broader emotions associated with this affective state given possible demand effects.

Main Data Analysis

Linear mixed effects models were specified using the lmer function of the *lme4* package in R (version 1.1-7; Bates et al., 2014) to test the proposed hypotheses. This analytic approach was deemed appropriate given the nested structure of the data (repeated measurement occasions within participants) and ability of these models to examine interactions between categorical and continuous predictors without having to aggregate outcome scores. Pre-induction valence bias task ratings were adopted as dependent variables in analyses for hypothesis 1 and 3, with pre- and post-induction ratings used when testing hypothesis 2. In each model, consistent with Barr et al. (2013), a maximal random-effects structure was used where possible, with intercepts and slopes of predictors allowed to vary within participants. All continuous predictors were z-standardized and centered, with dummy coding used for two level categorical predictors and sum-to-zero coding used for predictors with more than two levels (i.e., gender). Type III Sums of Squares were used for all models testing interactions (Barr et al., 2013). Main effects of gender

were included as a covariate in all analyses.[2] *P*-values were determined using conditional F tests with Kenward-Roger correction of degrees-of-freedom using the *car* package in R (version 2.0-21; Fox & Weisberg, 2011; Luke, 2017). Profile likelihood-based confidence intervals are reported.

Results

Preliminary Analyses

Means and standard deviations for valence bias task percent negative ratings and reaction times captured before and after the state loneliness induction are presented in Supplemental Tables 1 and 2. As expected, average overall ratings for negative images were more negative than ambiguous images at pre-test, $t(1008) = -43.54$, $p < .001$, and post-test, $t(815) = -41.86$, $p < .001$, and they were also more negative than positive images at pre-test, $t(959) = 65.09$, $p < .001$, and post-test, $t(786) = 55.19$, $p < .001$. Given that ambiguity in this task was defined as images with the greatest standard deviation and reaction time in ratings (Neta & Brock, 2021), we also confirmed that this was the case. Correspondingly, standard deviations in percent negative ratings were greater for ambiguous images than negative images at pre-test, $t(684) = 33.36$, $p < .001$ and post-test, $t(577) = 35.24$, $p < .001$, and positive images at pre-test, $t(668) = 43.77$, $p < .001$, and post-test, $t(586) = 39.92$, $p < .001$. The same was true for average reaction times, with participants taking longer to rate ambiguous images than negative images at pre-test, $t(1149) = 16.55$, $p < .001$, and post-test, $t(983) = 16.84$, $p < .001$, and positive images at pre-test, $t(1143) = 22.10$, $p < .001$, and post-test, $t(964) = 22.82$, $p < .001$, supporting the validity of this measure (Neta & Brock, 2021).

[2] Gender was categorized as 'man,' 'woman,' or 'self-specified gender identity,' which included non-binary, two-spirit, transgender, agender, gender fluid, gender queer, demigender, questioning, or some combination of these.

As anticipated, the one-way repeated measures ANOVA examining changes in state loneliness across baseline, pre-induction, post-induction, and post-study questionnaires further yielded a significant main effect of time, $F(2, 1203) = 50.21$, $p < .001$. Post-hoc analysis with a Bonferroni adjustment revealed that participants reported significantly greater levels of state loneliness post-induction, relative to pre-induction (see Figure 2; Supplemental Table 3), $t(499) = -11.20$, $p < .001$. In fact, levels of state loneliness significantly differed across all timepoints except for between baseline and post-questionnaires, confirming that effects of the induction were limited to the duration of the study. Given possible demand effects of the loneliness induction, we also confirmed that there were concomitant changes in positive and negative affect that would be expected to accompany genuine changes in loneliness. There was a significant main effect of time for each one-way ANOVA examining changes in state positive affect, $F(3, 1381) = 76.58$, $p < .001$, and state negative affect, $F(3, 1412) = 18.86$, $p < .001$. For positive affect, as expected, significant differences were observed between all timepoints except for between post-test and post-questionnaire (see Figure 2; Supplemental Table 3). Most critically, participants reported significantly lower levels of positive affect post-induction, relative to pre-induction, $t(498) = 9.05$, $p < .001$. For negative affect, as in the time course for loneliness (see Figure 2; Supplemental Table 3), participants' self-reported levels of negative affect significantly differed across all timepoints except for baseline and post-questionnaires. Moreover, as expected, levels of negative affect were significantly greater post-induction, relative to pre-induction, $t(498) = -2.60$, $p = .050$. This broader pattern of emotional changes (i.e., changes in positive and negative affect) accompanying state loneliness supports the assertion that participants were experiencing actual changes in loneliness, versus demand characteristics of the induction.

Main Analysis

Hypothesis 1

A linear mixed model with chronic loneliness and stimulus type (social, non-social) tested whether chronic loneliness was associated with more negative interpretations of ambiguous social relative to non-social stimuli. There were significant main effects of stimulus type, $F(1, 588) = 20.31$, $b = 2.85$, 95% CI [1.61, 4.09], $p < .001$, and gender, $F(1, 586) = 11.92$, $b = 7.30$, 95% CI [4.32, 10.27], $p < .001$. This suggests that ratings were more negative for ambiguous social images, relative to non-social images (see Supplementary Table 1), and for women ($M = 57.40$, $SD = 16.90$) relative to men ($M = 50.20$, $SD = 18.5$), with no significant differences observed for those who self-specified their gender identity ($M = 52.99$, $SD = 17.30$). Moreover, the chronic loneliness x stimulus type interaction was not significant, $F(1, 588) = 0.10$, $b = -0.20$, 95% CI [-1.44, 1.04], $p = .753$. Additional parameter estimates are presented in Table 2.

Hypothesis 2

To test the association between chronic loneliness and negative ratings of social and non-social ambiguity as a function of state loneliness, we conducted a linear mixed model with chronic loneliness, state loneliness (i.e., time: pre-induction, post-induction), and stimulus type. There was a significant main effect of state loneliness, $F(1, 904) = 7.57$, b = -2.07, 95% CI [-3.53, -0.60], $p = .006$, and a state loneliness x stimulus type interaction, $F(1, 495) = 11.89$, b = 3.04, 95% CI [1.31, 4.77], $p < .001$. Although ratings of ambiguous stimuli became less negative (i.e., more positive) from pre- to post-induction overall, follow-up analyses indicated that this change was especially pronounced for non-social stimuli, b = 2.07 (0.75), $p = .006$, and there was a non-significant shift in the opposite direction for social stimuli, b = -0.98 (0.75), $p = .193$ (see Figure 3). The three-way interaction of chronic loneliness x state loneliness x stimulus type,

$F(1, 495) = 0.57$, $b = 0.67$, 95% CI [-1.06, 2.40], $p = .451$, was not significant. Although not specified in the pre-registration, this model additionally included anxiety and depression as covariates to build on prior work which omitted these relevant internalizing symptoms from analyses. Parameter estimates are presented in Table 3.

Hypotheses 3a and 3b

Finally, to examine whether chronic loneliness would be associated with more negative interpretations of ambiguous social versus non-social stimuli for those with elevated symptoms of anxiety (Hypothesis 3a) or depression (Hypothesis 3b), we conducted two separate linear mixed models with chronic loneliness, stimulus type, and either generalized anxiety (Model 3a) or depression (Model 3b) symptoms on pre-induction ratings. Both the main effect of anxiety, $F(1, 852) = 6.36$, $b = 2.01$, 95% CI [0.45, 3.56], $p = .012$, and interaction of anxiety with stimulus type, $F(1, 585) = 7.48$, $b = -1.93$, 95% CI [-3.31, -0.55], $p < .01$, were significant. While individuals with greater anxiety rated ambiguous images more negatively overall, follow-up analyses indicated that this association was driven primarily by ratings of non-social images, b = 2.01, 95% CI [0.45, 3.57], relative to social images, b = 0.08, 95% CI [-1.48, 1.64] (see Figure 4). On the other hand, the three-way interaction of chronic loneliness x stimulus type x anxiety symptoms was not significant, $F(1, 585) = 0.08$, $b = -0.18$, 95% CI [-1.41, 1.06], $p = .781$. Parameter estimates are presented in Table 4.

The second model was analogous to that of the first but substituted anxiety with depressive symptoms. Here, there was a significant depression x stimulus type interaction, $F(1, 585) = 4.23$, $b = -1.62$, 95% CI [-3.15, -0.08], $p = .040$, such that greater depressive symptoms were more strongly associated with increased negative ratings for non-social ambiguity, b = 1.68, 95% CI [-0.07, 3.42], relative to social ambiguity, b = 0.06, 95% CI [-1.68, 1.80] (see Figure 4).

Although there was a marginal association between greater depressive symptoms and more negative overall ratings, $F(1,851) = 3.56$, $b = 1.68$, 95% CI [-0.06, 3.41], $p = .060$, this effect did not reach significance. The same was true for all other interactions (see Table 4).

Discussion

Evolutionary theories posit that chronic loneliness is linked to negative interpretation bias for ambiguous social information (Cacioppo & Hawkley, 2010; Qualter et al., 2015). The present study was the first to test this assumption by examining how associations among chronic loneliness and interpretation bias vary according to the type of ambiguity (i.e., social, non-social) and levels of state loneliness, and anxiety and depression symptoms in a large undergraduate sample. Interestingly, state, but not chronic, loneliness was associated with interpretations of ambiguity. Moreover, this association was specific to non-social stimuli, with negative ratings *decreasing* from before to after the state loneliness induction. While greater anxiety and depressive symptoms predicted more negative ratings of non-social ambiguity, neither moderated the association between chronic loneliness and negative interpretation bias. Implications of these findings and directions for future work are discussed below.

The finding that interpretations became more positive following the state loneliness induction, irrespective of levels of chronic loneliness, may contradict the prospect that negative biases in the latter are triggered by momentary increases in state loneliness. However, this increased positivity following a socially threatening experience is not without precedent. Although ours was the first study to examine interpretation biases in state loneliness specifically, past research has documented that social exclusion elicits more positive biases in attention, interpretation, and memory (DeWall et al., 2009; 2011; Xu et al., 2015). As in the present study, it may be that social threats paradoxically lead individuals to become more attuned to positive

emotional information. DeWall et al. (2011) suggest this may evince a self-regulatory process manifesting as more positive changes in cognition, apart from changes in conscious affect. That this did not arise for social ambiguity, specifically, may reflect the adaptive need for individuals to continue to monitor social threats in their environment when faced with momentary feelings of disconnection (Cacioppo & Hawkley, 2009). At the same time, the fact that interpretation biases were not associated with chronic loneliness suggests that other mechanisms may be implicated when feelings of loneliness persist.

One possibility is that individuals vary in how they behaviourally respond to momentary feelings of loneliness, irrespective of interpretations. Some individuals might respond more adaptively by focusing on reaffirming relationships likely to meet their needs for belongingness, perhaps relying on self-regulatory abilities to do so (Stavrova et al., 2021). Yet, others might demonstrate maladaptive, hostile behavioural responses (e.g., social withdrawal) that ultimately perpetuate their feelings of loneliness because they lack the self-control or social competence to overcome this impulse (Stavrova et al., 2021). Thus, the failure to upregulate positive social interpretations in response to state loneliness might be linked with chronic loneliness only for those with poorer self-regulatory abilities. While possibly suggesting the need for greater emphasis on behavioural, relative to cognitive, responding to state loneliness in present theoretical models (Qualter et al., 2015), future work is clearly needed. Such work should take a trajectory-based, holistic approach by examining individual differences in affective, cognitive, and behavioural responses to state loneliness.

Methodological characteristics might also help to explain the non-significant associations of chronic loneliness and negative interpretation bias observed here, which contrast with previous vignette-based work (e.g., Lau et al., 2021; Nombro et al., 2022; Okruszek et al., 2021).

Although we aimed to extend this work using the valence bias task – which captures more automatic interpretations of visual ambiguity – this may have engaged disparate cognitive processes to those involved when attributing meaning to vignettes in a relatively slow, effortful manner. Indeed, some research suggests that at shorter stimulus latencies, the default response to ambiguity is negative and driven by bottom-up mechanisms (Petro et al., 2018). At longer stimulus latencies, however, top-down control processes come online and help to override this initial response, facilitating more positive interpretations (Neta & Tong, 2016; Pierce et al., 2023). As such, the relative failure to engage top-down control mechanisms may be responsible for negative interpretation biases elsewhere observed in chronic loneliness, suggesting this effect may emerge primarily in tasks that allow for more effortful versus automatic responding to ambiguity. Prior work utilizing tasks that present in-depth descriptions of ambiguous social scenarios may also better capture the complexity of real-world social ambiguity, relative to the task used in our study. While our task allowed us to examine rapid interpretations of *visual* ambiguity, an important yet understudied aspect of the social environment, this difference may underlie non-significant findings for social stimuli in particular. Future work should manipulate both stimulus latency and type (e.g., complexity) to better understand the conditions under which expected negative interpretations of ambiguity in chronic loneliness become apparent. Although there is some evidence that variability in valence bias is related to discrete unipolar measures of positivity and negativity (Pierce et al., 2024), future work might also explore the unique association of negative and positive interpretation biases with loneliness, as opposed to conceptualizing these biases along a continuum (as in the valence bias task; Neta & Brock, 2021). Despite not being able to examine this possibility in our study, positive and negative biases have been found to operate as related but distinct constructs in other clinically relevant

experiences (e.g., social anxiety; Baumgardner et al., 2024). As such, the extent to which positive and negative interpretations are differentially related to loneliness remains an exciting direction for future research.

Although the null association between chronic loneliness and negative interpretations remained even among those with elevated anxiety or depression, both symptoms were themselves associated with a more broadly negative bias. This finding is largely consistent with prior work linking anxiety or depression and negative interpretation biases across a range of ambiguous stimuli (Hirsch et al., 2016; Neta & Brock, 2021; Park et al., 2016; Petro et al., 2021). In anxiety, such biases are said to arise through heightened threat processing, leading to perception of threat in otherwise ambiguous environments (Wilson et al., 2006). This perception elicits increases in state anxiety that only reinforce threat evaluation mechanisms, thus strengthening negative representations of ambiguity and resulting in more negative interpretations. In depression, negativity biases are often framed as arising from latent negative schemas (i.e., memories, beliefs) that lead individuals to selectively attend to negative cues in the environment (Beck & Haigh, 2014; Clark et al., 1999; Everaert et al., 2017). That similar associations were described across anxiety and depressive symptoms supports the prospect that negative interpretation biases represent a shared mechanism across internalizing symptoms (Jopling et al., 2021). Future work (e.g., utilizing interpretation bias tasks perhaps better suited to capturing putative links with chronic loneliness) might examine whether greater loneliness can precipitate this mechanistic pathway. In other words, it may be that negative interpretations mediate the chronic loneliness-internalizing symptom association. Although the present study was not equipped to answer this mechanistic question, it represents an interesting direction for future research.

This research was not without limitations. First, this study was conducted online rather than in a controlled, laboratory environment. This was consistent with our prioritization of recruiting a sufficiently large sample to detect the three-way interactions included in study aims. However, the environment in which participants completed the study may have detracted from study engagement. Indeed, there was an increase in the number of valence bias trials removed from pre- to post-induction, suggesting that participant fatigue may have increased over time. Despite this, our use of rigorous data exclusion procedures supports the quality of our data. Second, we omitted a control group in the current study. This decision was made based on prior work documenting the stability of the valence bias over time (Neta et al., 2018; Harp et al., 2022). Moreover, it allowed us to again maximize our sample to detect three-way interactions. Yet, our findings could be further substantiated in future work both incorporating a control group and testing participants in a laboratory setting. Future work might also address any potential limitations introduced by our use of the UCLA Loneliness Scale as an indicator of chronic loneliness (Russell, 1996). While recent work has argued that this scale captures the persistence of loneliness (Qualter et al., 2021), representing one definition of chronicity, the original scale does not reference a specific temporal period in which loneliness occurs. As such, it remains possible that participants had different timeframes in mind when reporting on their usual loneliness, possibly influencing the strength of associations in our study. That participants completed the chronic loneliness questionnaire (among others) after the loneliness induction represents an additional potential source of variability. While effects of the induction likely dissipated substantively while participants were completing the post-induction valence bias task

and demographic questionnaires preceding the measure of chronic loneliness[3], this influence cannot be completely ruled out.

Taken together, this study was the first to test whether chronic loneliness is associated with more negative interpretation biases for social versus non-social information, particularly during momentary increases in state loneliness or for those with elevated internalizing symptoms. We extend prior work by demonstrating that state (but not chronic) loneliness is associated with more positive interpretations of non-social ambiguity, and that greater symptoms of anxiety and depression are associated with more negative interpretations. If replicated, this may support the prospect that cognitive responses to social threat experiences are highly nuanced and extend beyond increased negativity, depending on the type of information subject to interpretation (DeWall et al., 2011). Findings also substantiate involuntary, automatic negative biases in anxiety and depression, and the clinical utility of training programs already being used to facilitate more positive interpretations of ambiguity (Harp et al., 2022; Harp et al., 2023). On the other hand, our findings did not the support the prospect that social threat interpretations underlie chronic loneliness. Although future work is needed, extant theoretical models emphasizing social threat hypersensitivity (e.g., Cacioppo & Hawkley, 2009) may require updating to better account for such vulnerability. Future work should examine not only cognitive, but behavioural and motivational processes, which together elucidate the pathway to chronic loneliness.

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[3] Levels of positive and negative affect and state loneliness had returned to baseline levels by the end of the study, as evidenced by non-significant differences between scores reported at baseline and post-questionnaires (see Results section).

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Table 1

Sample Characteristics

Variable	N (%) unless otherwise specified
Age, *M (SD)*	20.50 (3.70)
Gender	
Woman	431 (73%)
Man	136 (23%)
Prefer to specify gender identity[a]	23 (4%)
Prefer not to answer	1 (< 1%)
Biological sex	
Female	448 (76%)
Male	141 (24%)
Prefer not to answer	2 (< 1%)
Race/ethnicity	
East Asian	206 (35%)
White	133 (23%)
South Asian	95 (16%)
South-East Asian	39 (7%)
White/East Asian	20 (3.5%)
Middle Eastern	13 (2%)
Black	9 (1.5%)
White/Indigenous	9 (1.5%)
White/South Asian	9 (1.5%)

White/Hispanic/Latinx	8 (1%)
Latinx	6 (1%)
White/Middle Eastern	6 (1%)
Additional race/ethnicity specified[b]	26 (4%)
Don't know/Prefer not to answer	12 (2%)
Income	
$10,000-24,999	65 (11%)
$25,000-75,000K	109 (19%)
>$75,000	201 (34%)
Unsure	155 (26%)
Prefer not to answer	61 (10%)
Education Level	
High school diploma or less	513 (87%)
University degree or more	78 (13%)
Chronic loneliness, *M (SD)*	46.28 (11.57)
Generalized anxiety symptoms, *M (SD)*	9.53 (5.76)
Depressive symptoms, *M (SD)*	23.03 (12.28)

Notes. Total *n* = 591.

[a]Additional gender identities specified include non-binary, agender, gender fluid, gender queer, demigender, transgender, questioning, and two-spirit.

[b]Additional racial/ethnic identities specified include Hispanic/Latinx, Native Hawaiian, South-Asian/Hawaiian, White/South-East Asian, Central Asian, Indigenous, Indo-Fijian, mixed race,

South-East Asian/Hawaiian, White/East Asian/Hispanic/Latinx, White/Filipino, and White/Hawaiian.

Table 2

Fixed Main Effects and Interactions of Chronic Loneliness x Stimulus Type on Negative Ratings of Ambiguous Images

Predictor	*b*	*SE*	Df_1	Df_2	*F*-value	*p* value	95% CI
Gender (woman)[a]	7.30	0.02	1	586	11.92	**< .001**	**[4.32, 10.27]**
Gender (self-specify)[a]	2.56	0.04	1	586	11.92	.462	[-4.25, 9.38]
Stimulus type	2.85	0.01	1	588	20.31	**< .001**	**[1.61, 4.09]**
Chronic loneliness	0.91	0.71	1	858	1.62	.204	[-0.47, 2.30]
Chronic loneliness x Stimulus	-0.20	0.01	1	588	0.10	.754	[-1.44, 1.04]

Note. Total $n = 590$; analyses excluded $n = 1$ participant who preferred not to report their gender.

[a]Reported contrasts represent comparisons with men as reference level.

Table 3

Fixed Main Effects and Interactions of Chronic Loneliness x Stimulus Type x Time on Negative Ratings of Ambiguous Images

Predictor	*b*	*SE*	Df_1	Df_2	*F*-value	*p* value	95% CI
Gender (woman)[a]	6.39	1.56	1	491	10.18	**< .001**	**[3.33, 9.45]**
Gender (self-specify)[a]	-1.72	3.60	1	491	10.18	.634	[-8.78, 5.35]
Anxiety	0.39	1.00	1	491	0.15	.697	[-1.57, 2.35]
Depression	0.79	1.14	1	491	0.47	.490	[-1.44, 3.01]
Stimulus type	2.64	0.72	1	931	13.41	**< .001**	**[1.23, 4.06]**
Chronic loneliness	0.31	0.93	1	613	0.11	.738	[-1.50, 2.13]
Chronic loneliness x Stimulus	-0.39	0.72	1	931	0.29	.588	[-1.81, 1.02]
Time	-2.07	0.72	1	904	7.57	**.006**	**[-3.53, -0.60]**
Chronic loneliness x Time	-0.61	0.75	1	904	0.66	.416	[-2.08, 0.86]
Time x Stimulus	3.04	0.88	1	495	11.89	**< .001**	**[1.31, 4.77]**
Chronic loneliness x Time x Stimulus	0.67	0.89	1	495	0.57	.451	[-1.06, 2.40]

Note. Total *n* = 497 participants; analyses excluded 2 participants who did not complete the CESD or GAD-7, respectively.

[a]Reported contrasts represent comparisons with men as reference level.

Table 4

Fixed Main Effects and Interactions of Chronic Loneliness x Stimulus Type x Anxiety (Depression) on Negative Ratings of Ambiguous Images

Predictor	*b*	*SE*	Df_1	Df_2	*F*-value	*p* value	95% CI
Model 3a							
Gender (woman)[a]	7.23	1.52	1	583	11.80	**< .001**	**[4.26, 10.20]**
Gender (self-specify)[a]	2.29	3.49	1	583	11.80	.512	[-4.52, 9.09]
Stimulus type	2.91	0.69	1	585	17.77	**< .001**	**[1.56, 4.26]**
Chronic loneliness	-0.10	0.80	1	853	0.02	.899	[-1.65, 1.45]
Chronic loneliness x Stimulus	0.70	0.71	1	585	0.98	.323	[-0.68, 2.08]
Anxiety	2.01	0.80	1	852	6.36	**.012**	**[0.45, 3.56]**
Chronic loneliness x Anxiety	0.81	0.71	1	854	1.30	.255	[-0.58, 2.20]
Anxiety x Stimulus	-1.93	0.71	1	585	7.48	**.006**	**[-3.31, -0.55]**
Loneliness x Anxiety x Stimulus	-0.18	0.63	1	585	0.08	.781	[-1.41, 1.06]
Model 3b							
Gender (woman)[a]	7.22	1.53	1	583	11.64	**< .001**	**[4.25, 10.20]**
Gender (self-specify)[a]	2.46	3.49	1	583	11.64	.481	[-4.36, 9.28]
Stimulus type	3.23	0.72	1	585	19.99	**< .001**	**[1.82, 4.65]**
Chronic loneliness	-0.14	0.89	1	851	0.02	.877	[-1.87, 1.59]
Chronic loneliness x Stimulus	0.77	0.78	1	585	0.96	.471	[-0.76, 2.30]
Depression	1.68	0.89	1	851	3.56	.060	[-0.06, 3.41]
Chronic loneliness x Depression	0.48	0.68	1	852	0.51	.476	[-0.84, 1.80]
Depression x Stimulus	-1.62	0.79	1	585	4.23	**.040**	**[-3.15, -0.08]**

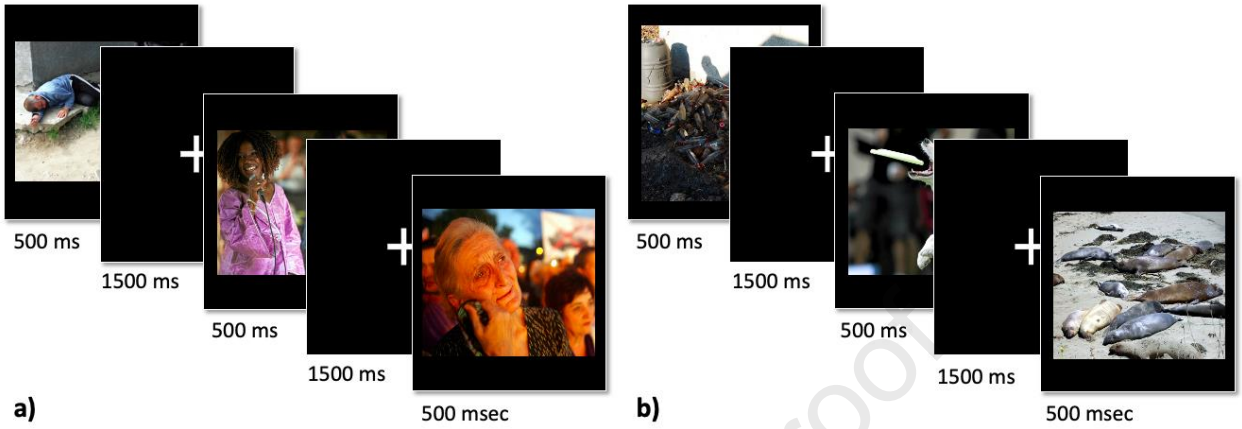
Loneliness x Depression x Stimulus	-0.58	0.60	1	585	0.92	.338	[-1.75, 0.60]

Note. Total $n = 589$; analyses excluded $n = 1$ participant who preferred not to report their gender and 2 participants who did not complete the CESD or GAD-7, respectively.

[a]Reported contrasts represent comparisons with men as reference level.

Figure 1

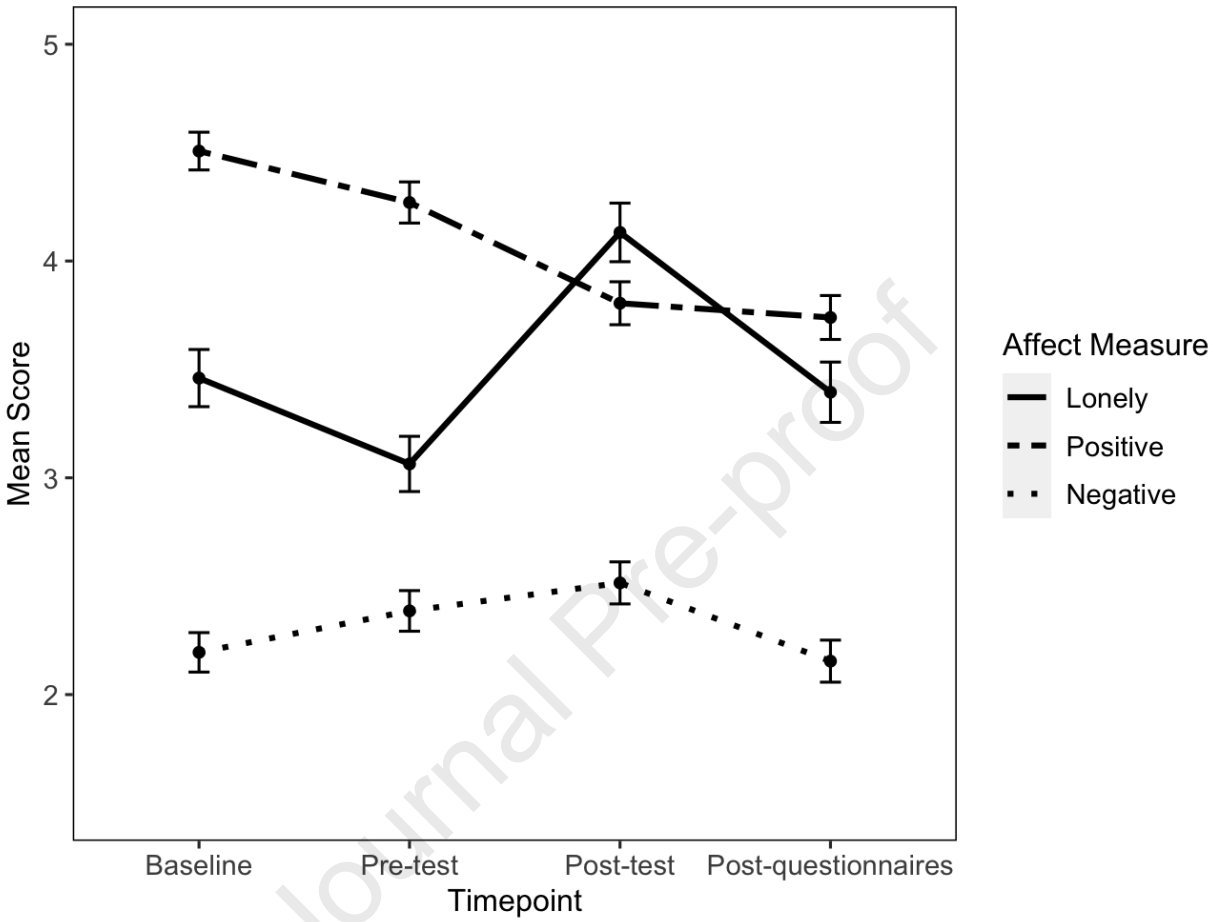
Valence Bias Task Stimuli



Note. Valence bias task depicting a) social stimuli; b) non-social stimuli.

Figure 2

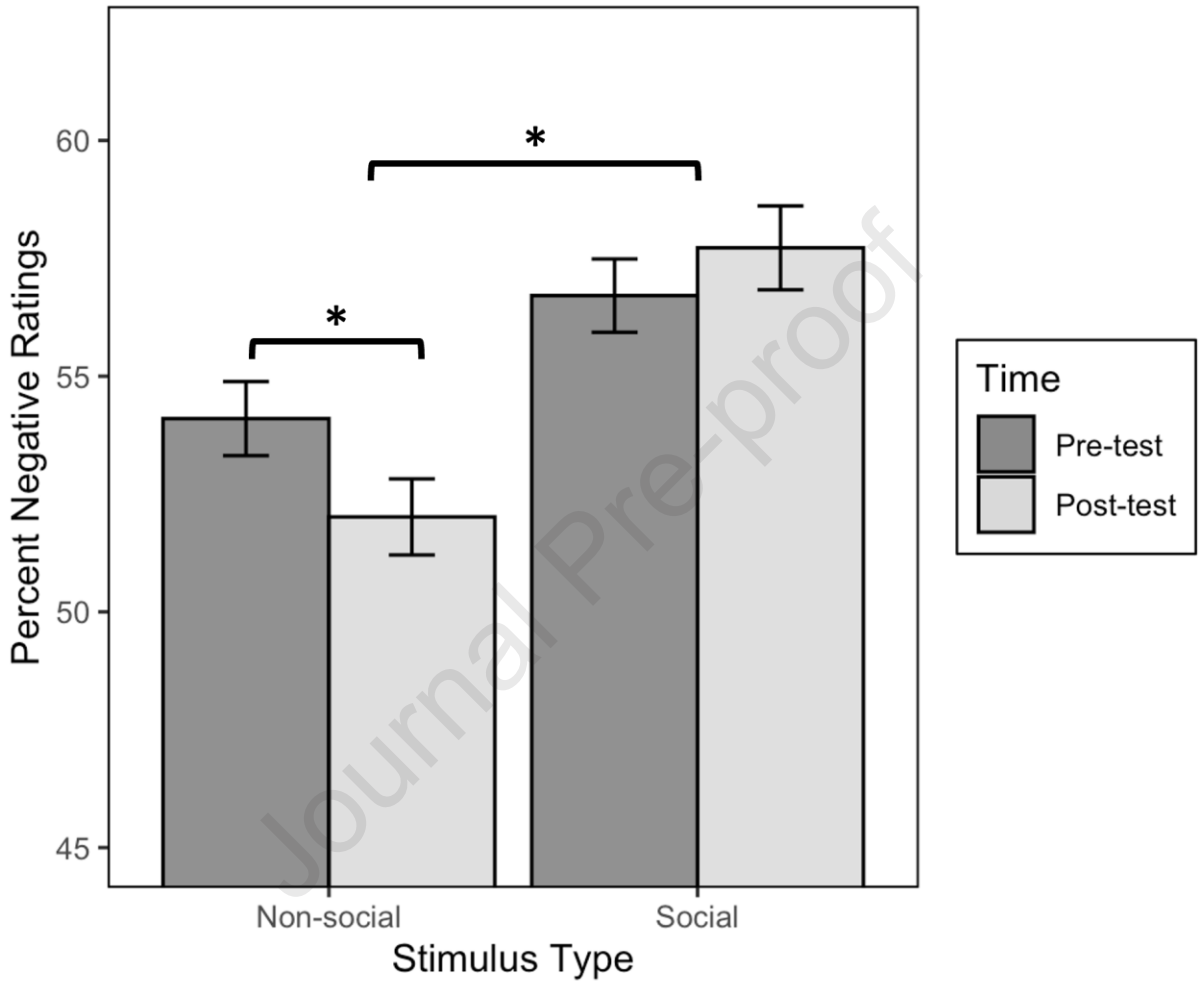
Changes in State Loneliness, Positive Affect, and Negative Affect Over Time



Note. State loneliness and positive and negative affect ratings over the course of the study. Error bars indicate ± 1 standard error.

Figure 3

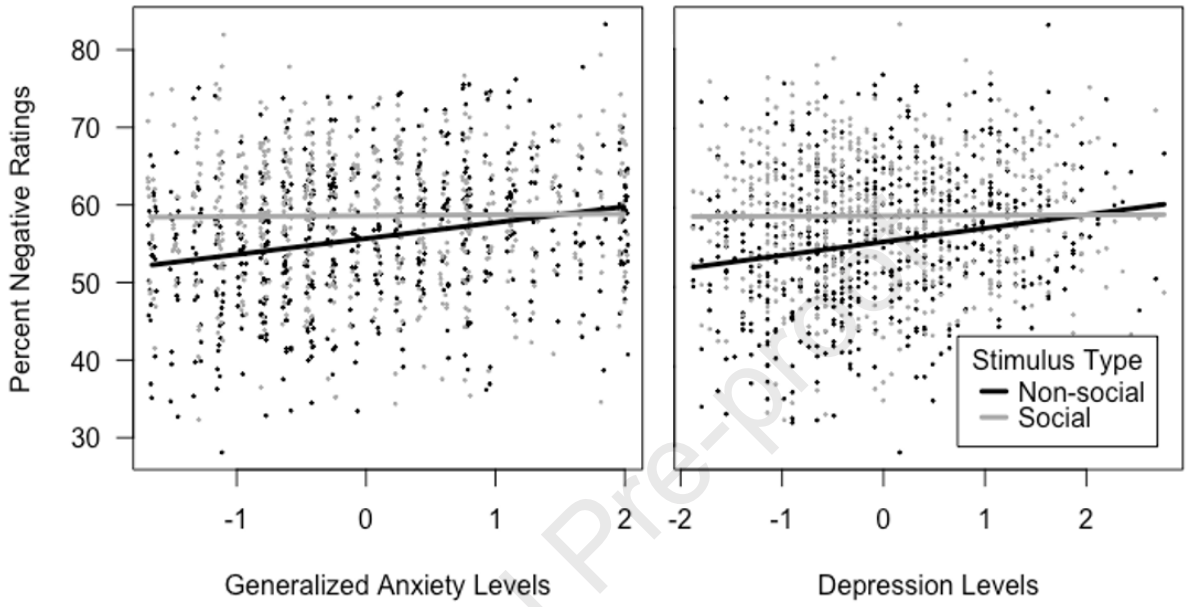
Percent Negative Ratings of Ambiguity by Stimulus Type Before and After the State Loneliness Induction



Note. Ambiguous social images were rated more negatively relative to non-social images overall, with non-social images rated more positively at post-induction relative to pre-induction.

Figure 4

Stimulus Type x Generalized Anxiety and Depression Levels Predicting Percent Negative Ratings of Ambiguity



Note. Increasing levels of generalized anxiety and depression were accompanied by increased negative ratings of non-social ambiguous images.

Highlights

- Chronic loneliness was not associated with negative interpretation bias.
- State loneliness predicted more positive interpretations of non-social ambiguity.
- Greater anxiety and depression predicted more negative interpretations.

Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Bronwen Grocott reports financial support was provided by Government of Canada Social Sciences and Humanities Research Council. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.