THE EFFECT OF LONELINESS ON PROCESSING OF EMOTIONAL SOCIAL INFORMATION IN YOUNG AND OLDER ADULTS

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ABSTRACT

Loneliness selectively alters the way in which people perceive, process, and interact with information in their social world. Specifically, lonely individuals display a hypersensitivity to social threats and a propensity to preferentially process emotionally valenced social information. Although loneliness influences both attention and memory for socioemotional information in young, the impact in older adulthood has not yet been considered. Here we examine whether loneliness differentially modulates attention biases and incidental memory for distracting social and emotional stimuli in young and older adults. Forty young (24 female and 16 male) and forty older adults (22 female and 18 male) performed a digit parity task during which they were asked to make parity decision as they were simultaneously shown distracting social and nonsocial images varying in valence (positive, neutral, negative). Participants were then given a surprise memory recognition task. Higher levels of loneliness in young adults predicted lower distractibility for negative and neutral social stimuli relative to positive stimuli. In contrast, lonely older adults were less accurate on the attention task when negative social distractors were presented. Loneliness did not influence incidental memory in either young or older adults, although recognition was greater for negative social images. We discuss the implications of these findings for theoretical perspectives of the influence of loneliness on socioemotional processing and suggest future research directions.

BIOGRAPHICAL SKETCH

Laëtitia Mwilambwe-Tshilobo was born in Kinshasa, Democratic Republic of the Congo. After completing her schoolwork at The America School of Kinshasa in 2006, Laëtitia moved to the United States where she received a Bachelor of Arts with a major in Neuroscience from The College of Wooster in May 2010. She then received a Master of Science degree in Biology with a concentration in Neuroscience at the University of Hartford in 2012, and worked as a research assistant at the University of Pennsylvania School of Medicine for three years. Laëtitia is currently a graduate student in the Laboratory of Brain and Cognition in the Department of Human Development at Cornell University where she has been working on social cognition and aging research.

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INTRODUCTION

The subjective perception of social isolation, known colloquially as loneliness, has been shown to have adverse effects on psychological functioning and wellbeing. Loneliness is associated with increased morbidity and mortality (Hawkley & Cacioppo, 2003; Peplau & Perlman, 1982; Tilvis et al., 2004), poor overall health (Tijhuis, De Jong-Gierveld, Feskens, & Kromhout, 1999), disability (Bisschop et al., 2003), depression (Weeks, Michela, Peplau, & Bragg, 1980), and cognitive decline (L. C. Hawkley & Cacioppo, 2007; Tilvis et al., 2004; Wilson et al., 2007). In addition, loneliness is also characterized by implicit hypervigilance for social cues (S. Cacioppo, Balogh, & Cacioppo, 2015; S. Cacioppo, Bangee, et al., 2015), biased memory for negative and positive social information (Gardner, Pickett, Jefferis, & Knowles, 2005), and increased negative perceptions of social relationships (Christensen & Kashy, 1998; Jones, Sansone, & Helm, 1983; Wittenberg & Reis, 1986).

These selective changes in how lonely individuals attend to and utilize emotionally valenced social information is argued to serve critical evolutionarily adaptive functions meant to diminish the possibility of social rejection and facilitate detection of social opportunities so that salutary social bonds can be reinstated (J. T. Cacioppo, Cacioppo, & Boomsma, 2014). However, research on the effects of loneliness on the processing of social information has largely focused on younger adults, and the few studies on older adults have primarily been on the long-term effects of loneliness on cognitive decline and health. Given that older adults experience normative socioemotional and cognitive changes, understanding how social information is processed in older adults may provide insight into the association between loneliness and cognition decline with age. Therefore, the goal of the present study is to examine how loneliness influences processing of emotionally valent social information in younger and older adults. The following sections will review current models of loneliness, its association with aging, and the theoretical implications of loneliness on the socioemotional goals of older adults. We will then report the results of a study examining age-related differences in the effects of loneliness on attention and incidental memory recognition.

Conceptualizing loneliness

Loneliness has been conceptualized from various perspectives. The most widely accepted view of loneliness is that it is due to discrepancies between one's desired and actual level of social connectedness (Weiss, 1973). According to the social needs model of loneliness, each person's relationships must adequately satisfy an inherent set of social needs and failure to fulfill these needs would be distressing. Weiss (1973) further extends this theory by suggesting that social deficiencies are not simply caused by a lack of attachment, but can also stem from a lack of other needs such as social integration or reassurance of worth. In this model, loneliness is based on two type of needs: social loneliness and emotional loneliness. Social loneliness is due to a lack of engagement within a social network causing the individual to experience feelings such as aimlessness, boredom, or social exclusion. Emotional loneliness is thought to be due to the absence of a reliable attachment figure such as a parent or spouse.

Cacioppo and Hawkley (2009) further expanded the definition of loneliness to include a third component: negative perceptions of relationships. They argue that these negative interpretations are not only distressing but are also aversive. Consistent with these views, Rokach (2012) suggests loneliness is not driven by the number of friends or the amount of contact a person has with others, but instead is caused by the subjective perception of the situation. This suggests that a person who is socially isolated may not necessarily feel lonely, while another may feel lonely despite being surrounded by others. Thus, although sometimes used interchangeably, social isolation and loneliness represent two distinct concepts. Social isolation can be operationalized as the absence of social contact, whereas loneliness is the subjective perception of deficiencies in either the quantity or quality of social relationships. For the purpose of this paper, we will focus on the subjective experience of loneliness with some consideration of objective social isolation in young and older adults.

Loneliness and social information processing

As previously discussed, loneliness is an aversive state, however, because we are intrinsically motivated to form and maintain meaningful social relationships (Baumeister & Leary, 1995), loneliness

may serve the purpose of bringing awareness to the state of our social connections and facilitating social reconnection (J. T. Cacioppo et al., 2014). Research in this area has mostly been conducted in young adults, with evidence suggesting that social information has greater salience in individuals with high self-reported levels of loneliness (S. Cacioppo, Bangee, et al., 2015). Indeed, prior research has found that lonely individuals are generally more sensitive to social cues (Bangee, Harris, Bridges, Rotenberg, & Qualter, 2014; J. T. Cacioppo & Hawkley, 2009; J. T. Cacioppo, Norris, Decety, Monteleone, & Nusbaum, 2009; S. Cacioppo, Balogh, et al., 2015; S. Cacioppo, Capitanio, & Cacioppo, 2014). This heightened focus, particularly for negative social cues, is thought to facilitate detection of cues that may signal rejection. For example, when lonely individuals are shown emotionally valenced social and nonsocial images or words, they pay greater attention to negative social images compared to positive or neutral images (S. Cacioppo, Balogh, et al., 2015).

Recent neuroimaging studies provided support for the altered processing of negative social information. In young adults, when lonely and non-lonely participants were shown social and nonsocial emotionally valenced images, lonely participants showed greater activation of the visual cortex for negative social images and decreased activation in the ventral striatum (a region involved in reward processing) when showed positive social images (J. T. Cacioppo et al., 2009). In an electromagnetic imaging study, lonely individuals were able to more quickly discriminate threatening social versus nonsocial images when compared to individuals with lower levels of loneliness (S. Cacioppo, Bangee, et al., 2015) . Taken together with the behavioral studies, this would suggest that loneliness not only orients attentional resources towards negative social information, but that it may facilitate perception of negative social cues.

In addition to selective changes in attention, lonely young adults also show changes in post-attentive processing of negative and positive social cues. For instance, young adults with high levels of loneliness show higher incidental recall for socially relevant information (Gardner et al., 2005). However this was not only limited to negative social information. Participants with higher levels of loneliness also

showed better recall for positive social information, suggesting that although loneliness may be associated with a bias in encoding negative social information, this attention bias may extend to all social cues.

Loneliness is also associated with negative perceptions of social interactions (Wittenberg & Reis, 1986) and negative expectations about the way one is perceived (Jones et al., 1983). Lonely people view themselves negatively and show greater discrepancies than non-lonely people between perception of themselves and their ideal selves (Peplau & Perlman, 1982). They also view others more negatively which reinforces the subjective perception that they are unable to form relationships. These inaccurate perceptions can be amotivional especially when interpersonal opportunities arise because they expect to be rejected or have unrealistic expectations of their ideal social relationship (Jones, 1982; Roock & Peplau, 1982). Such pessimistic expectations for social interactions can thus become a self-fulfilling prophecy—driving lonely individuals to behave more negatively towards others and consequently experiencing more negative social interactions (Cacioppo & Hawkley, 2009). Overall the combination of inadequate social connectedness and deficits in social behavior perpetuates a cycle of negative reinforcement that increases social withdrawal and impairs social perception in lonely individuals.

Socioemotional Selectivity Theory

Most studies investigating the relationship between social information processing and loneliness were conducted in young adults, with few studies examining this association in older adulthood. There is currently no adult lifespan developmental theory of loneliness, however because loneliness is a psychological construct with emotional implications, characterizing loneliness in terms of age-related changes in the socioemotional goals of young and older adults may provide insights into understanding the relationship between socioemotional functioning and loneliness across the adult lifespan.

According to the socioemotional selectivity theory (SST), as the time horizons shrink (i.e. shifting from open ended to limited) people's motivational goals change from information seeking to emotionally gratifying (Carstensen, Isaacowitz, & Charles, 1999). Older adults are more likely to invest more time and attention to family and close friends, whereas younger adults seek out new social relationships. This shift

in motivational goals also influences cognition in that older adults typically show a ‘positivity bias’ in attention and memory functioning (Mather & Carstensen, 2005).

Older adults’ social network composition also reflect changes in their motivational goals. Across adulthood there is a selective narrowing of social networks for more meaningful social relationships. Older adults preferentially spend more time with close social partners further maintaining well-established social bonds (Carstensen et al., 1999), whereas young adults are more motivated to gain more social knowledge and therefor are more likely to seek novel social partners (Fredrickson & Carstensen, 1990). Seeing that feelings of loneliness raise from perceived deficits in both quality and quantity of social relationships, failure to fulfil the socioemotional goal of maintaining meaningful social bonds in late adulthood may make older adults especially vulnerable to the negative effects of loneliness.

Aging and loneliness

Despite age-differences in the socioemotional goals of young and older adults, no explicit theoretical or empirical work has examined how loneliness modulates the positivity bias in attention and memory functioning in older adults. Thus far, research focused on loneliness and aging has consistently shown that loneliness compromises cognitive function in older adults. Specifically, lonely older adults show impairments in global cognitive function (Tilvis et al., 2004), processing speed (O'Luanaigh et al., 2012), immediate (O'Luanaigh et al., 2012; Shankar, Hamer, McMunn, & Steptoe, 2013), and delayed (Shankar et al., 2013) memory. In addition, although the prevalence of loneliness is stable across the lifespan, loneliness in older adults predicts greater cognitive decline (Donovan et al., 2016; Shankar et al., 2013; Tilvis et al., 2004), and doubles the risk of Alzheimer’s disease (Boss, Kang, & Branson, 2015; Wilson et al., 2007). While evidence suggests that loneliness has adverse effects on cognitive functioning, it remains uncertain whether lonely older adults may be potentially more vulnerable to cognitive dysfunction or whether loneliness is an antecedent to or a consequence of cognitive decline.

In addition to poor cognitive function in lonely older adults, age-differences in socioemotional goals may also have important implications for the way in which older adults attend to and utilize emotional information. For instance, using a visual attention paradigm to assess attentional bias Mather

and Carstensen (2003) demonstrated that compared with younger adults, older adults spent more time looking at positive relative to negative faces. Similar results were found when examining overt visual attention using eye-tracking, during which older adults preferentially looked at happy faces versus unhappy faces (Isaacowitz, Wadlinger, Goren, & Wilson, 2006). Other studies have also shown a positivity bias in memory. Memory for positive relative to negative information is greater in older adults whereas younger adult show better memory for negative information (Charles, Mather, & Carstensen, 2003). Compared with younger adults, older adults better remember positive versus negative information across multiple paradigms including autobiographical and long-term memory (Charles et al., 2003), as well as working memory (Mikels, Larkin, Reuter-Lorenz, & Carstensen, 2005).

While loneliness and aging are both associated with biases in processing of emotionally valenced information, it remains uncertain how these two factors interact in older adulthood. In the present study, we examined whether loneliness modulates the positivity effect in attention and memory in older adults. We adopt a visual attention task including both emotionally-valenced and neutral stimuli to assess attentional bias towards positive, neutral, and negative distracting social and nonsocial images. Further a surprise subsequent memory test was conducted to assess the impact of loneliness on incidental memory for viewed items. Given that loneliness is associated with faster processing of negative social information we predicted that loneliness in both young and older adults would result in decreased performance on the attention task and poorer subsequent recall of positive images.

METHODS

Participants

Forty young adults (60% female; *M*=19.9, SD=1.37, age range=18-22) and forty older adults (55% female; *M* age=68.9, SD=5.70, range=60-85) were included. All participants were screened for depression (young adults: Beck Depression Index; old adults: Geriatric Depression Scale) and older adults were screened for dementia using the Mini Mental State Exam. Data from 2 young adults and 3 older adults were excluded due to low accuracy on the digit parity task (incorrect responses on more than one-third of trials). All procedures were approved by the Institutional Review Board at Cornell University.

Behavioral measures

Loneliness. Loneliness was assessed using the 20-item Revised UCLA (R-UCLA) scale which measures general loneliness and degree of satisfaction with one's social relationships (D. Russell, Peplau, & Cutrona, 1980). The R-UCLA scale has been shown to have high reliability (D. Russell et al., 1980) and validity (D. W. Russell, 1996). Participants were presented with statements such as "*How often do you feel that there is no one you can turn to?*" and asked to indicate how often they felt the way described by the statement (1= Never; 2= Rarely; 3=Sometimes; 4= Usually; 5=Always). Higher values indicate a greater loneliness. In this study loneliness was treated as a continuous variable, and any references to high or low loneliness made are based on our specific sampling distribution.

Behavioral covariates. To assure the specificity of findings to our criterion variable, loneliness, and to test for possible mediation effects, two covariates were included in the analyses: Mood (Brief Mood Introspection Scale; BMIS) and objective social isolation (Social Network Index; SNI). Covariates were treated as continuous variables. Mood has previously been shown to regulate gaze, a proxy of attention, (Isaacowitz, Toner, Goren, & Wilson, 2008; Isaacowitz, Toner, & Neupert, 2009) and memory (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Charles et al., 2003) in older adults. Therefore, general mood was assessed using the BMIS which consisted of ten adjectives describing different emotions (e.g., sad, annoyed, content, gloomy, happy). Participants were instructed to indicate if the adjective that described their current feelings based on a scale of 1 (definitely do not feel) to 5 (definitely feel). Appropriate items were reverse scored so that higher numbers indicated more positive mood.

We also controlled for objective measures of social isolation which represents the level of contact participants have with others. The three components of the social network considered are based on the structural dimension of the Berkman-Syme Social Network Index (Berkman & Syme, 1979), which measures the number of social ties, closeness with members of the network, and frequency of contact. The size of the network was assessed by asking the participant about the number of people in the network. For example, "*Please state the number of people [in total] who are so close to you at the present time that*

you: *can talk to them about personal affairs, can get help from them in everyday matters, and/or enjoy spending your leisure time with them [please consider family members, friends, colleagues, etc*.]*"*.

Stimuli

Digit parity task. A modified version of the digit parity task (Wolford & Morrison, 1980) was used to examine the effect of loneliness on attentional bias to valenced nonsocial and social stimuli. Stimuli for the task consisted of digits 1 to 9, and two sets of 120 images from the International Affective Picture System (IAPS; Lang et al., 2001). Images were categorized as social (with people) or nonsocial (without people). Social and nonsocial images were subsequently subdivided by valence based on the IAPS images normative valence ratings. A total of 80 negative, 80 neutral, and 80 positive images were selected (half social and half nonsocial within each valence group). Negative images were selected if their valence rating < 4.2, neutral images had a valence rating between 4.2 and 6.2, and positive images had ratings >6.2. Selected images were matched across arousal rating and the gender of the persons in the picture. The task consisted of 120 experimental trials 20 images for each valence/content combination. Each digit was randomly paired but were constrained such that on half of the trials the digits were congruent (both odd and even) and incongruent for the remaining trials (one odd and one even).

Recognition task. To assess bias in incidental memory, all participants were given a surprise old/new recognition test on 60 images used in the digit parity task. The images were randomly selected from the social and nonsocial categories used in the digit parity task; accordingly, there were 30 nonsocial images (10 positive, 10 negative, and 10 neutral) and 30 social images (10 positive, 10 negative, and 10 neutral). The two sets of images were matched on valence and arousal.

Procedure

Prior to the digit parity task, participants were asked to provide demographic information (age, gender, and handedness) and to complete the BMIS to assess their mood. Next we administered the digit parity task for which stimulus presentation and response recordings were obtained using PsychoPy2 software. Once complete, participants were given 20 practice digit parity task trials. Images selected for

the practice trials were neutral in valence and nonsocial. During the practice and test trials participants were presented with a distractor image flanked by two digits. Each trial began with the presentation of a fixation cross in the center of the computer screen for 500 ms and followed by a 500 ms blank interval (white screen). The distracting image was presented alone for 100 ms, after which it remained on the screen but was flanked by a digit to the left and right for 150 ms. Participants were instructed to ignore the images and to indicate whether the two digits were congruent or incongruent. Once the digit parity task was complete, participants were given two filler tasks for 10 minutes. Participants were then given an unexpected recognition task. Each image appeared in the center of the screen and remained on the screen until participants responded.

Statistical analysis

Prior to analysis of digit parity data, an outlier analysis was conducted across each of the six trial types to identify any response times (RT) that were two standard deviations above or below the mean for each participant. We used linear mixed models to evaluate how loneliness influenced digit parity RT, accuracy, and memory recognition for valenced nonsocial and social information. Loneliness, content (nonsocial, social), and valence (positive, neutral, negative) were entered as fixed factors into the model using the lme4 package in R Version 3.4.1 (Bates, Mächler, Bolker, & Walker, 2015). All effects were taken as random at the participant level, and condition estimates and statistics are reported at the population level. P-values were obtained using the *car* package (Fox & Weisberg, 2011).

Table 1

Sample demographics

	Young Adults			Older Adults		
Gender	*n*		*%*	*n*		*%*
Female	24		60	22		55
Male	16		40	18		45
Variable	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Age	19.9	1.37	4	68.95	5.70	25
R-UCLA	41.72	9.14	40	35.25	9.54	39
MMSE	29.22	0.89	3	28.27	1.74	7
Depression*	-0.14	0.77	3.01	-0.08	0.96	3.64
SNI	23.8	10.34	43	25.25	10.04	51

R-UCLA (Loneliness); MMSE (Mini Mental State Exam); SNI (Social network index).
** Depression score is based on the z-score of the Beck Depression Index for young adults and the Geriatric Depression Scale for older adults.*

RESULTS

Loneliness and attentional processing of emotional information

To examine age differences in the effects of loneliness on attentional processing of socioemotional information, we used a linear mixed effects model to determine whether the effect of loneliness on accuracy and RT differed in young and older adults as they made parity decisions while viewing distracting social and nonsocial valenced images. Loneliness, group (young, old), content (nonsocial, social), and valence (positive, neutral, negative) and their interactions were included as fixed

effects. Participant was included as a random intercept. Statistical significance was determined by likelihood ratio tests of the full model with the effect in question against the model without the effect in question. Results of the regression analysis for RT and accuracy are shown in Table 2.

To determine how loneliness influences attention to emotionally valenced social information is processed in young and older adults, we first examined the RT during the parity decision task. Loneliness has previously been characterized by hyper-vigilance for social threats that facilitates processing for negative social cues. Across valence type, participants were slower at making parity decisions when negative distractors were presented relative to positive distractors ($\beta = -0.20$, SE =0.09, $\chi^2 = 5.27$, $p < 0.05$). While there was no other significant main effects, there was a significant content × valence interaction ($\beta = -0.54$, SE =.018, $\chi^2 = 9.27$ $p < 0.01$). Overall, participants responded slower during trials with social negative distractors compared to social positive trials.

The model also identified a significant group × content × valence interaction ($\beta = 1.21$, SE =0.03, $\chi^2 = 11.40$ $p < 0.001$). In younger adults, RT during trials with negative social distractors was slower compared to neutral and positive social distractors. However, older adults showed no difference in RT between valenced distractors during trials that contained social or nonsocial content. A significant loneliness × group × content × valence interaction, ($\beta = -0.02$, SE =0.01, $\chi^2 = 7.61$, $p < 0.01$) was found, demonstrating that age-differences in the effect of loneliness on attention to valence of social and nonsocial distractors (Figure 1). Increasing levels of loneliness in young adults was related to faster reaction irrespective of distractor valence. However, when the image valence was social in content, higher loneliness was associated with faster RT only for negative and neutral, but not for positive distractors. Older adults did not show this same tendency, they responded with the same speed to valenced social and nonsocial distractors.

Next, we investigated whether parity decision accuracy was modulated by stimulus category. We found no significant main effects for accuracy, however there was a significant group x valence interaction ($\beta = -12.06$, SE = 5.08, $\chi^2 = 5.59$, $p < 0.05$). Young adults were more accurate when the distractor was positive while older adults were more accurate when the distractor was negative. We found

Table 2

LMM estimates of fixed effects predicting digit parity decision response time and percent accuracy from loneliness, group, distractor content, and distractor valence.

Coefficients	*Dependent Variable*					
	Response time			Accuracy		
	β	*SE*	*p-value*	β	*SE*	*p-value*
Fixed Effects						
(Intercept)	0.98	0.21	<.001***	86.88	4.21	<.001***
Loneliness	-0.01	0.01	.18	0.16	0.11	.14
Group	-0.27	0.42	.53	0.10	8.42	.99
Content	-0.02	0.07	.81	0.95	2.08	.65
Valence	-0.20	0.09	.02*	-0.98	2.54	.70
Loneliness × Group	0.01	0.01	.27	-0.07	0.21	.72
Loneliness × Content	0.00	0.00	.71	-0.03	0.05	.61
Group × Content	0.04	0.14	.80	-0.05	4.15	.99
Loneliness × Valence	0.00	0.00	.05	0.07	0.06	.25
Group × Valence	0.28	0.18	.12	-12.06	5.09	.02*
Content × Valence	-0.54	0.18	<.01**	-9.79	5.09	.05
Loneliness × Group × Content	-0.00	0.00	.65	0.02	0.10	.85
Loneliness × Group × Valence	-0.01	0.00	.21	0.32	0.13	.01*
Loneliness × Content × Valence	0.01	0.00	.01*	0.29	0.13	.02*
Group × Content × Valence	1.21	0.36	<.001***	-0.76	10.17	.94
Loneliness × Group × Content × Valence	-0.02	0.01	<.01**	0.11	0.26	.66
R^2	.88			.78		

* indicates $p < .05$; ** indicates $p < .01$; $p < .001$

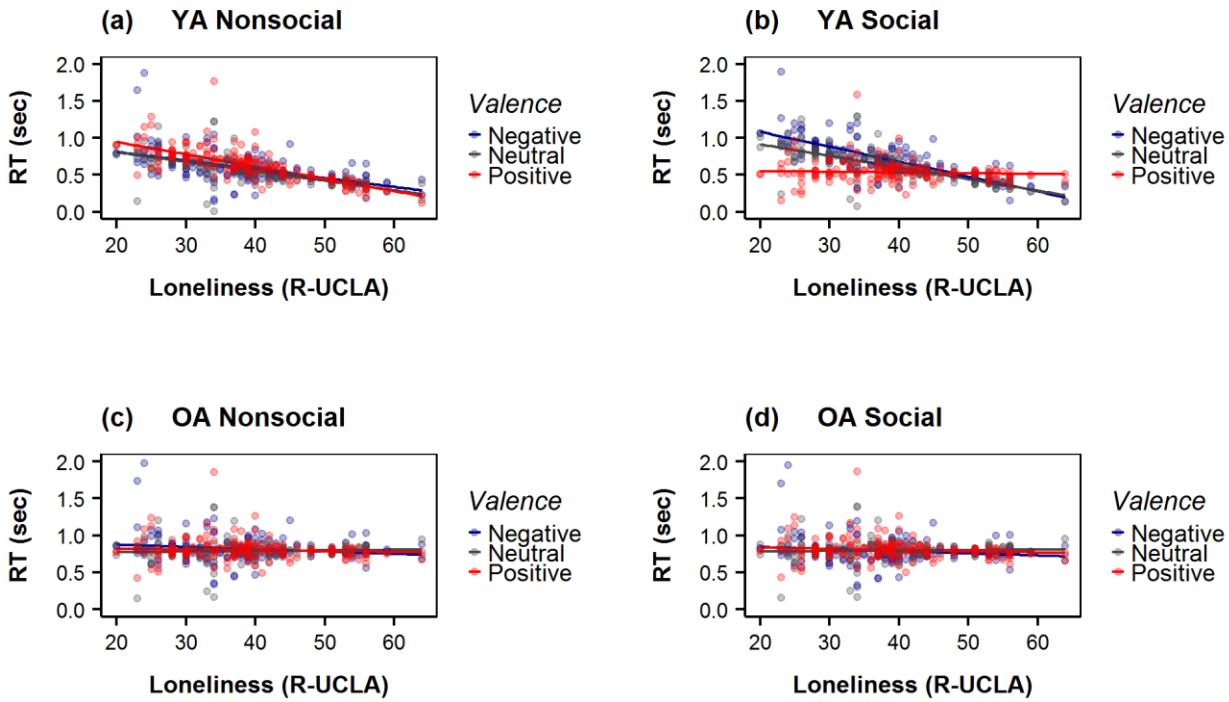

Figure 1. Digit parity decision response time (RT) as a function of loneliness in young and older adults. Top panel shows the predicted RT for negative, neutral, and positive (a) nonsocial distractors and (b) social distractors in young adults. Similarly, the bottom panel show the predicted RT for valenced (c) nonsocial (d) social distractors in older adults.

that loneliness influenced this group by valence interaction in older adults only ($\beta = 0.32$, SE = 0.13, $\chi^2 = 6.11$ $p < 0.05$). Older adults with higher levels of loneliness were more accurate on the positive distractor trials.

Subsequent memory

Using the images presented during the digit parity task we examined whether loneliness modulated the positive memory bias in older adults using an incidental recognition memory task. Similar to the digit parity analysis, a linear mixed model regression was used to examine the effects of loneliness on hit rate (Hits), false alarm rate (FA), and corrected recognition (Hits − FA). Regression results are reported in Table 3 (see appendix for graphical representation of model trends).

Table 3

LMM analyses predicting corrected recognition (CR), hit rate (Hits), and false alarm rate (FA) from loneliness, group, image content, and image valence during the memory recognition task.

	CR			Hits			FA		
Coefficients	β	SE	p-value	β	SE	p-value	β	SE	p-value
Fixed Effects									
(Intercept)	0.50	0.02	<.001***	0.62	0.02	<.001***	1.25	0.12	<.001***
Loneliness	0.03	0.02	.19	0.02	0.02	.17	-0.02	0.12	.87
Group	-0.05	0.04	.16	-0.02	0.03	.53	0.33	0.24	.18
Content	0.16	0.02	<.001***	0.13	0.01	<.001***	-0.30	0.09	<.001***
Valence	-0.08	0.02	<.001***	-0.10	0.02	<.001***	-0.23	0.11	.04*
Loneliness × Group	0.02	0.04	.61	-0.01	0.03	.78	-0.29	0.24	.23
Loneliness × Content	-0.02	0.02	.22	-0.01	0.01	.39	0.07	0.09	.44
Group × Content	-0.05	0.03	.10	-0.02	0.03	.42	0.28	0.18	.11
Loneliness × Valence	-0.01	0.02	.63	-0.01	0.02	.76	0.04	0.11	.71
Group × Valence	0.05	0.04	.20	-0.01	0.04	.80	-0.59	0.22	.01*
Content × Valence	0.08	0.04	.05*	0.12	0.04	<.01**	0.39	0.22	.08
Loneliness × Group × Content	-0.03	0.03	.38	0.01	0.03	.65	0.41	0.18	.02*
Loneliness × Group × Valence	-0.00	0.04	.90	0.00	0.04	.91	0.09	0.22	.68
Loneliness × Content × Valence	-0.00	0.04	.93	0.02	0.04	.61	0.21	0.22	.34

Table 3 cont.

	CR			Hits			FA		
Coefficients	β	SE	p-value	β	SE	p-value	β	SE	p-value
Group × Content × Valence	-0.01	0.08	.94	0.05	0.07	.49	0.52	0.44	.23
Loneliness × Group × Content × Valence	-0.02	0.08	.82	0.00	0.07	.98	0.19	0.44	.66
R^2	.60			.58			.60		

* $p < .05$; ** $p < .01$; *** $p < .0$

There were no significant main effects of loneliness or age on corrected recognition, however participants showed better recognition for social images ($\beta = 0.16$, SE = 0.02, $\chi^2 = 95.70$, $p < 0.001$), and negative images were most frequently recognized ($\beta = -0.08$, SE = 0.02 $\chi^2 = 15.53$, $p < .001$). While we found no significant interaction between factors, there was a marginal trend for better recognition of negative social images ($\beta = 0.08$ SE = 0.04 $\chi^2 = 3.80$ $p = .05$). Analysis of the hit rates showed all participants had better recall for social images compared to nonsocial images ($\beta = 0.13$ SE = 0.01 $\chi^2 = 79.26$ $p < .001$), and greater recognition for negative images more than neutral or positive images ($\beta = -0.10$ SE = 0.02 $\chi^2 = 31.21$ $p < .001$). In addition, all participants had higher hit rates for negative social distractors ($\beta = 0.11$ SE = 0.03 $\chi^2 = 10.63$, $p < .001$). We also analyzed the false alarm rate and found that participants had lower false alarm rates for social images ($\beta = -0.30$ SE = 0.09 $\chi^2 = 11.01$ $p < .001$), negative images ($\beta = -0.23$ SE = 0.11 $\chi^2 = 4.42$ $p < .05$). We did find that older adults had a more difficult time discriminating old and new positive images whereas young adults showed no difference ($\beta = -0.59$ SE = 0.22 $\chi^2 = 11.01$ $p < .05$) and that for nonsocial images higher levels of loneliness predicted lower FA rate in old adults relative to young adults ($\beta = 0.41$ SE = 0.18 $\chi^2 = 5.11$ $p < .05$).

Mood ratings

We obtained mood ratings using the BMIS to control for possible contribution of mood on memory performance. A one-way ANOVA on the average mood ratings with group (young, older) as a between-subjects factor. Consistent with prior studies we found a significant group difference in mood, $F(1, 72) = 65.13$, $p < .001$, with older adults reporting more positive mood (M =56.53, SD = 1.08) compared to young adults (M = 46.42, SD = 0.70).

Due to differences in mood ratings between young and older adults we repeated the data analysis for corrected recognition (CR) to control for these differences. The main effect of content ($\beta = -0.17$, SE = 0.17 $\chi^2 = 92.72$, $p < .001$) and valence remained significant ($\beta = -0.07$, SE = 0.02 $\chi^2 = 11.921$, $p < .001$). Interestingly there was a significant loneliness × mood × group × content interaction ($\beta = 0.1$, SE = 0.03 $\chi^2 = 10.03$, $p < .001$).

DISCUSSION

In young adults, loneliness facilitates processing of negative social cues (J. T. Cacioppo et al., 2009; S. Cacioppo, Balogh, et al., 2015; S. Cacioppo, Bangee, et al., 2015) and is associated with memory biases for social information irrespective of valance (Gardner et al., 2005). This paper examined whether these effects were also present in older adults given that prior research has demonstrated a propensity for older adults to display a positivity bias in attention and memory. In the present study, we examined the effect of loneliness on attention and incidental memory for emotionally valenced social and nonsocial stimuli in young and older adults. Our results revealed that higher levels of loneliness influenced attentional processing in young but not older adults. Loneliness was related to decreased attention across all valence types for nonsocial images and decreased attention for negative and neutral social images. Loneliness did not affect memory recognition in either young or older adult. Instead we found that irrespective of loneliness, all participants reliably recognized negative social images.

The first goal of this study was to investing whether the attentional biases previously reported in lonely young adults were also present in older adults. Based on previous work on the effects of loneliness on attention to social cues, showing enhanced early processing of negative social cues (J. T. Cacioppo et al., 2009; S. Cacioppo, Balogh, et al., 2015) we expected that our findings for the digit parity task would show attentional bias away from negative social cues. Our results for the young adults are consistent with this work showing that individuals with higher self-reported loneliness demonstrated less distractibility for negative social images relative to positive images. Bangee et al. (2014) also found that lonely young adults initially fixate onto negative stimuli but then divert their gaze away from it. Since accuracy was not affected by the speed of response time to make parity decisions, young adults with higher loneliness may be reallocating attention away from negative social stimuli.

Studies looking at age differences in detecting social threats suggest that the ability to quickly detect threatening social information is maintained among older adults despite differences in age-related emotional attention (Mather & Knight, 2006; Ohman, Lundqvist, & Esteves, 2001). Since loneliness is associated with a hypervigilance to social threats in young adults, we expected that it would have a

similar effect on attention for negative social images in older adults. However this hypothesis was not supported. Further, we did not find a positivity bias in attention in older adults previously reported in other studies (Mather & Carstensen, 2003). Although attention in older adults was equivalent across all stimuli, higher loneliness was related to better accuracy for positive stimuli. This could be interpreted to mean that digit parity decisions where easier to make when the stimuli presented was positive, but only if the person was lonely. However, these results should be interpreted with caution considering that accuracy was near ceiling (over 90%).

The second goal of this study was to examine whether loneliness modulated the positivity effect in memory in older adults. The present findings did not support this hypothesis as older adults did not show a positivity effect. Analysis of older adult participants' false-alarm rates did however show that a response bias for positive images. There are two possible factors that could contribute to our findings. The first is that the use of social images has been shown to impact age difference in memory for positive and negative stimuli. When comparing memory recognition for emotionally valenced social versus nonsocial images, there is evidence showing that older adults remember positive and negative social images equally (Hess, Popham, Dennis, & Emery, 2013; Hess, Popham, & Growney, 2017). The second factor is that although numerous studies demonstrate that older adults selectively remember and attend to positive information, not all studies have been able to replicate this effect (Reed, Chan, & Mikels, 2014). Future cross-sectional studies looking at the effects of loneliness on socioemotional processing in older adults will be important to better understanding of the impact of loneliness on cognitive function in late adulthood.

We also expected that young adults with higher levels of loneliness would have poorer recognition for positive stimuli, but this hypothesis was not supported. Interestingly, while young adults with higher levels of loneliness attended less to negative and neutral social images, their performance on the memory recognition task was similar to those with lower levels of loneliness. This would suggest that despite shorter encoding time for negative social stimuli reliable recognition for these items was not affected. Our findings for young adults on memory recognition conflicts with that of Gardner et al.

(2005) that found that lonely young adults showed increased incidental social memory for negative and positive cues. However this discrepancy in results may be due to methodological differences since their task examined recall for details of a written passage, whereas ours was focused on recognizing images presented on a screen. It may be that the images contained more contextual cues which could help with memory retrieval.

The maintenance of negative perception of social relationships is thought to play a role in maintaining feelings of loneliness (J. T. Cacioppo & Hawkley, 2009). Because recognition memory in young adults was not affected by attentional biases, it would be interesting to have future studies examine how these changes in attention affect social cognitive abilities. Specifically how emotional social information is utilized to interpret social cues. This may be of particularly interest in light of recent work showing altered structural and functional changes in areas of the brain that support attention, executive function, and social cognition in young (Kong et al., 2014; Layden et al., 2017; Nakagawa et al., 2015).

While this study was able to replicate previous findings for attention in lonely young adults, there are some limitations to be considered based on experimental design and study sample. The first is that we did not measure differences in image valence and arousal rating between young and old participants in this study. Perhaps this would have been useful in identifying whether loneliness modulated how participants viewed emotional social versus nonsocial stimuli. A second limitation was is that we had few participants in our old adult sample with high self-report of loneliness. Analysis of participant social network composition indicated that the older adults had larger and more diverse social networks compared to our young adults. Our young adults were lonelier than our older adults, and this may be because being in college is a unique transitional phase during which being away from close friends and family can result in lower sense of belonging (D. W. Russell, 1996).

In conclusion, the present study focused on examining the effect of loneliness on attentional and memory biases in young and older adults. We found that loneliness was related with decreased attention to negative social images in young but not older adults. Our results also showed that loneliness did not influence memory recognition in either young or older adults but that overall, all participants reliably

recognized negative social images. The findings of this study suggests that more research is needed within this area to examine how loneliness influences socioemotional goals in late adulthood. Thus, the conclusion to be drawn from this study is that despite the extensive loneliness literature, the impact of loneliness on processing emotional social information across adulthood is not well understood and continued experimental research is warranted.

APPENDIX

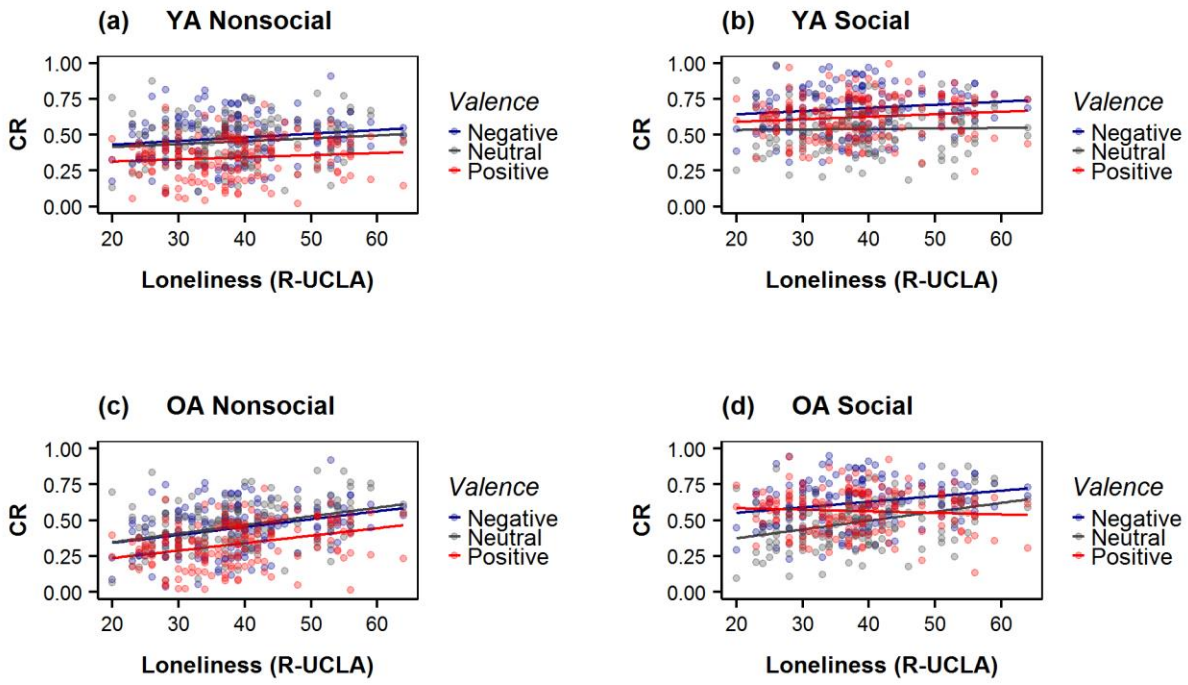

Figure A1. Estimate of corrected recognition (CR) for valence nonsocial and social images as a function of loneliness. (a-b) Estimates for young adults on nonsocial and social images. (c-d) Estimates for older adults (OA) on nonsocial and social images.

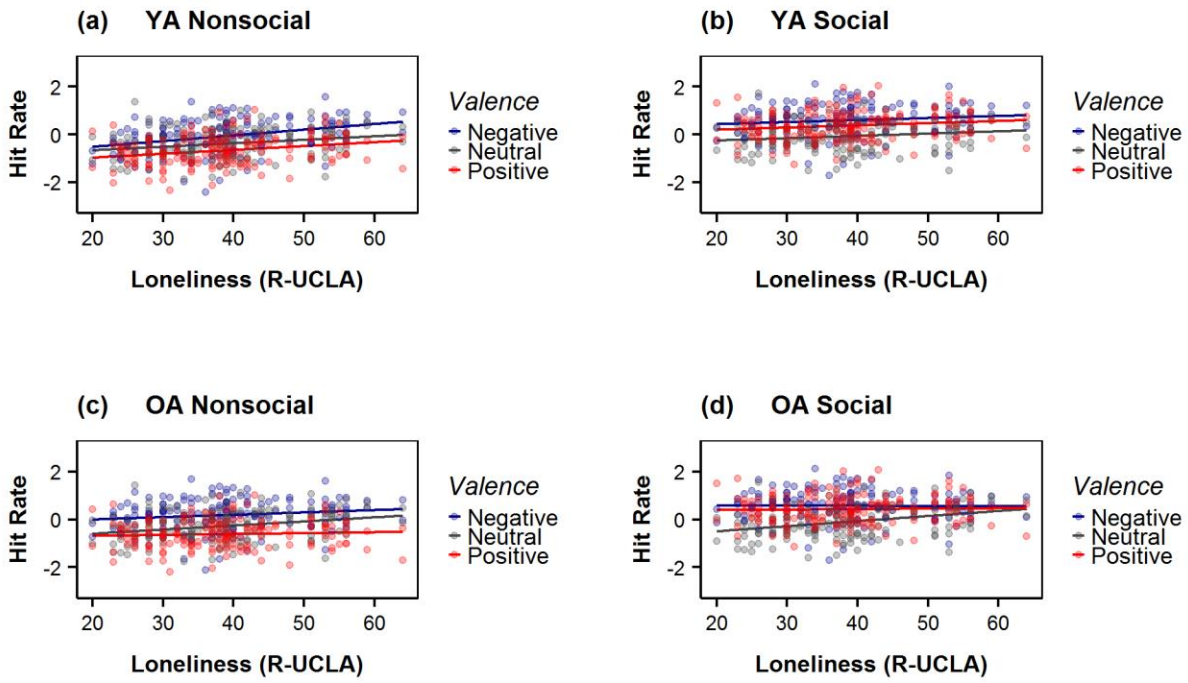

Figure A2. Estimate of hit rate for valence nonsocial and social images as a function of loneliness. (a-b) Estimates for young adults on nonsocial and social images. (c-d) Estimates for older adults (OA) on nonsocial and social images.

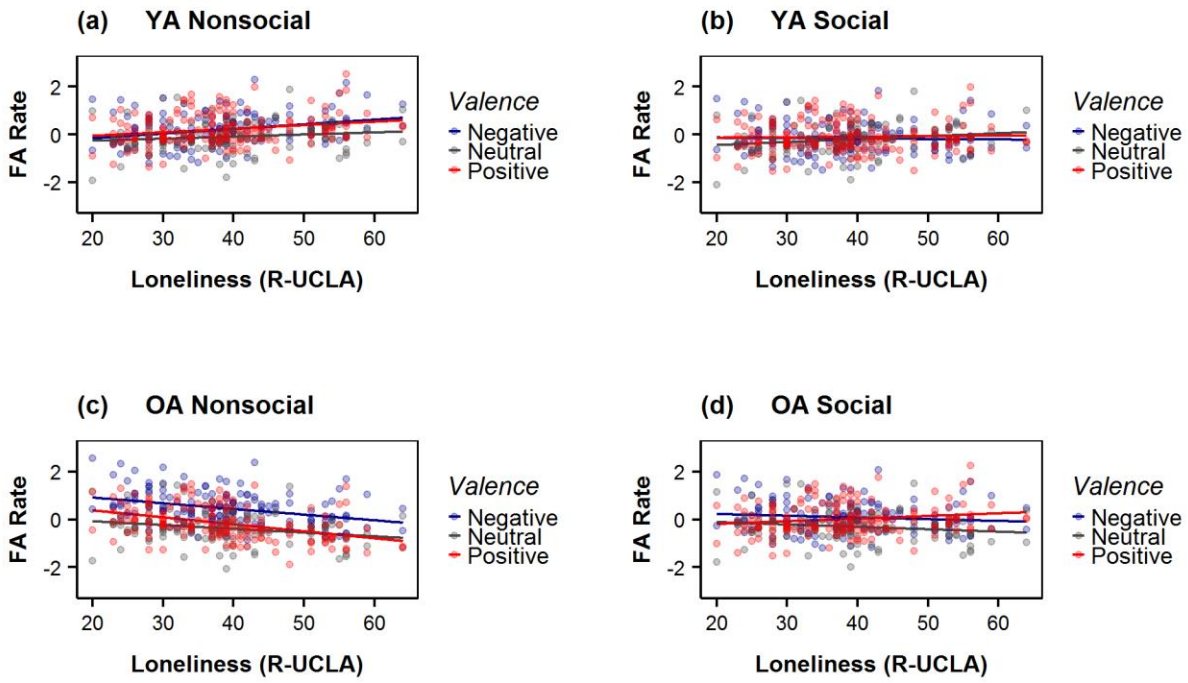

Figure A3. Estimate of false alarm rate for valence nonsocial and social images as a function of loneliness. (a-b) Estimates for young adults on nonsocial and social images. (c-d) Estimates for older adults (OA) on nonsocial and social images.

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