Loneliness Predicts Insensitivity to Partner Commitment

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ABSTRACT

People attend to their partners' pro-relationship behaviors (or commitment signals) which in turn leads to a positive adjustment in perceived strength of interpersonal bonds. This bond-confirming effect is stronger when the commitment signal entails some high cost (e.g., receiving an expensive birthday present), and by contrast, it is weaker when the commitment signal entails a low cost (e.g., receiving a wish of "Happy Birthday"). The present study explored how loneliness moderates sensitivity to commitment signals as well as their absence (i.e., situations where partners fail to signal commitment despite the demands of the situation). Studies with a Japanese student sample (Study 1), a Japanese community sample (Study 2), and an American sample drawn from users of Amazon Mechanical Turk (Study 3) found that loneliness is associated with an insensitivity to commitment signals: The lonelier the participant, the less likely he or she was to positively adjust perceived bond strength in response to a commitment signal. This relative insensitivity was observed irrespective of the costliness of the signal. On the other hand, loneliness did not predict differences in sensitivity to the absence of commitment signals. Implications of these results for the loneliness literature are discussed.

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1. Introduction

Dependable interpersonal relationships are an essential part of human life. Not surprisingly, being socially isolated is associated with a multitude of negative outcomes. To take just a few examples, socially isolated individuals are less happy (Argyle, 1987; Myers & Diener, 1995) and less healthy (House, Landis, & Umberson, 1988; Uchino, Uno, & Holt-Lunstad, 1999), and social isolation is associated with a higher risk of mortality (Holt-Lunstad, Smith, & Layton, 2010) even after controlling for potentially confounding variables, such as gender, age, and marital status. Moreover, research suggests that, aside from objective social isolation, subjective social isolation (or a feeling of loneliness) may be sufficient to cause various detrimental outcomes related to health and well-being (Cacioppo & Hawkley, 2009; Holt-Lunstad, Smith, Baker, Harris, & Stephenson, 2015). This is important because loneliness does not appear to be related to objective social isolation as tightly as we expect. In one study, the correlation was as small as 0.20 (Coyle & Dugan, 2012). Indeed, many people feel lonely despite being surrounded by others. How might this be so? Some of the answer, it appears, lays in the fact that many social partners are decidedly "fair-weather." According to Tooby and Cosmides (1996), fair-weather friends are self-interested partners who reap benefits from the relationship but never repay.

One way to distinguish true friends from fair-weather friends involves placing a person in a difficult or stressful situation, and then observing that person's willingness to stay in the relationship. This is known as a strain test in social psychology (Kelley, 1983; Shallcross & Simpson, 2012; Simpson, 2007) and a bond test in biology (Maestripieri, 2012; Zahavi, 1977), respectively. If a friend or romantic partner, after being elicited to do so, performs some high-cost pro-relationship behavior (e.g., taking time off work to help a partner move, nursing an ill partner back to health, etc.), that person can be trusted as someone who is "tried and true." The same also holds for when a high-cost pro-relationship behavior is spontaneously performed in absence of request or implicit solicitation. In both cases, the partner's willingness to provide instrumental or emotional support reflects their valuation of the relationship, and those who value the relationship are unlikely to exploit it. Therefore, making costly sacrifices for the sake of a relationship predicts various positive outcomes such as commitment, adjustment, and satisfaction (Stanley, Whitton, Sadberry, Clements, & Markman, 2006; Van Lange et al., 1997).

Some low-cost pro-relationship behaviors have also been demonstrated to enhance the perceived strength of interpersonal bonds. For example, actively sharing in a partner's positive experiences (or capitalization) strengthens bonds (Gable & Reis, 2010), and even minor benevolent interactions, such as giving complimentary remarks, seem to increase partner satisfaction (Matsumura & Ohtsubo, 2012). This may be because even apparently non-costly behaviors still require some inherent cost, which in turn honestly signals an interest in the target person (Ohtsubo et al., 2014; Ohtsubo & Tamada, 2016): By simply paying attention to your partner, you can share in achievements and commiserate in failures in a timely fashion, but as attention is a limited resource, this necessarily entails a cost in terms of lost opportunity.

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Based on the above arguments, Yamaguchi, Smith, and Ohtsubo (2015) maintained that people utilize their partners' pro-relationship behaviors as commitment signals to adjust the perceived strength of bonds. In their pilot study (an open-ended questionnaire), participants reported various real-life events that strengthened a bond with a specific partner (either a friend or a romantic partner). Irrespective of partner type, the reported events included an array of both high-cost and low-cost commitment signals. For example, planning and hosting a surprise party is a high-cost commitment signal, whereas simply wishing "happy birthday" is a low-cost commitment signal. Subsequent vignette studies conducted in Japan and America. (Studies 1 and 2 in Yamaguchi et al., 2015) confirmed that both high-cost and low-cost commitment signals are effective to confirm the strength of a bond, although high-cost signals are more effective. In addition, failure to produce a situationally appropriate commitment signal (e.g., forgetting to give a birthday wish) was found to have a detrimental effect on relationships by causing a weaker perceived bond.

The above studies show that people use their partners' commitment signals to up- and down-regulate the perceived strength of interpersonal bonds with their relationship partners. However, what happens when a person is deeply dissatisfied with the current state of his or her social relationships? What happens when a person is lonely? As loneliness is defined as an unpleasant emotional reaction to the mismatch between one's actual and desired social contacts (Peplau & Perlman, 1982), lonely individuals may be more motivated to pay attention to their partners' commitment signals than relatively well-connected individuals. In other words, loneliness might motivate an increased sensitivity, or hypersensitivity, to the sorts of relationship relevant behaviors that are useful for distinguishing "true" from "fair-weather" partners.

Hypothesis 1a. *Loneliness is associated with a propensity to positively adjust perceived bond strength in response to commitment signals.*

This is in line with the *social reconnection hypothesis* (Maner, DeWall, Baumeister, & Schaller, 2007), which posits that social exclusion motivates people to reconnect with others. Although some studies support this hypothesis (e.g., Derfler-Rozin, Pillutla, & Thau, 2010; Maner et al., 2007; Romero-Canyas et al., 2010), other studies suggest the existence of a diametrically opposite pattern: Socially excluded people tend to behave in a manner that inhibits reconnection (e.g., exhibiting more aggressiveness and hostility; see Baumeister, Brewer, Tice, & Twenge, 2007, for a review).

Apart from the social exclusion literature, findings in the loneliness literature are also mixed. Although some studies have shown that lonely individuals express greater interest in social stimuli (Gardner, Pickett, Jefferis, & Knowles, 2005) and positivity bias in perceiving unacquainted others (Christensen & Kashy, 1998; but also see Tsai & Reis, 2009), other studies have shown lonely individuals demonstrate increased negativity to social stimuli (see J. T. Cacioppo & Hawkley, 2009, for a review). Vanhalst et al. (2015), for example, found that chronically lonely individuals, identified by their stable self-reported loneliness throughout a four-year assessment period, responded to positive social stimuli (i.e., hypothetical vignettes depicting social inclusion episodes) less enthusiastically than other groups of people. This effect is not restricted to the hypothetical situations. In Hawkley, Preacher, and Cacioppo's (2007) experience sampling study, lonely individuals perceived positive social interactions less favorably than non-lonely individuals. Moreover, Cacioppo, Norris, Decety, Monteleone, and Nusbaum (2009) showed that for lonely individuals, the ventral striatum (i.e., a key component of reward circuits in the brain) responded less actively to positive social stimuli than positive non-social stimuli, while the opposite pattern (i.e., positive social stimuli are more rewarding than positive non-social stimuli) was found for non-lonely individuals. If the documented hyposensitivity to positive social stimuli extends to commitment signals, the following alternative hypothesis can be derived:

Hypothesis 1b. *Loneliness is associated with a propensity to negatively adjust perceived bond strength in response to commitment signals.*

The first purpose of our studies is to test these two competing hypotheses. In addition, we explore whether the costliness of commitment signals (i.e., high-cost vs. low-cost) moderates the hypothesized relation between loneliness and reactions to commitment signals.

Loneliness has also been shown to affect reactions to negative stimuli. For example, studies have revealed that lonely individuals are more sensitive to social exclusion via hypothetical vignettes than non-lonely individuals (Vanhalst et al., 2015), and that loneliness predicts increased levels of negative affect after experiencing negative social interactions (Hawkley et al., 2007). Moreover, Chang and colleagues found that loneliness increases the effect of negative life events, such as being the victim of sexual assault, on suicide risk (Chang, Sanna, Hirsch, & Jeglic, 2010; Chang et al., 2015). Thus, as people perceive a partner's failure to produce a situationally appropriate commitment signal as a threat to the relationship (Yamaguchi et al., 2015), this effect may be exacerbated by loneliness.

Hypothesis 2. *Loneliness is associated with a propensity to negatively adjust perceived bond strength in response to an absence of commitment signals.*

The second purpose of this study is to test this hypothesis. Notably for Hypothesis 2, we do not make the distinction between high vs. low-cost commitment signals because it is impossible to determine the costliness of unperformed behaviors. For example, if your friend fails to acknowledge your birthday, this could be conceived as either a failure to deliver a birthday wish (low-cost) or a failure to buy you a birthday gift (high-cost), partly depending on your expectations and situationally appropriate norms.

To test Hypotheses 1a, 1b, and 2, we conducted two vignette studies and re-analyzed the data from a comparable vignette study (i.e., Yamaguchi et al.'s, 2015, Study 2). In all three studies, participants were asked to imagine hypothetical scenarios, each of which described a situation where their partner (either a friend or romantic partner) performed a high-cost pro-relationship act, performed a low-cost pro-relationship act, or failed to perform a pro-relationship act in a relevant situation. After reading each scenario, participants rated how much positive or negative influence each act would exert on their relationship. Study 1 was a preliminary study involving a relatively small Japanese undergraduate student sample. Study 2 was an online replication of Study 1 involving a large Japanese community sample. In Studies 1 and 2, the scenario type (high-cost commitment signal, low-cost commitment signal, or commitment signal failure) was manipulated as a within-participant factor. Study 3 extended Studies 1 and 2 in two main dimensions. It involved an American (i.e., cross-cultural) sample, which was a sample of Amazon Mechanical Turk (MTurk) users, and manipulated the scenario type condition as a between, rather than within, -participants factor.

2. Study 1

2.1. Method

Participants were 78 undergraduates at two Japanese universities (49 females, 29 males; $M_{age} = 19.35$ years, $SD_{age} = 1.20$). Participants filled out a questionnaire in exchange for 500 Japanese yen (500 JPY $\approx$ $5). Study 1 employed a 2 (relationship type: friend or romantic partner) × 3 (signal: high-cost signal, low-cost signal, or signal failure) factorial design with relationship type as a between-participants factor and signal as a within-participant factor.

The first part of the questionnaire consisted of 15 hypothetical scenarios regarding commitment signals (five scenarios for the high-cost signal, low-cost signal, and signal failure conditions, respectively). Participants were asked to imagine that the events described in the

scenarios had occurred with either a real friend or romantic partner depending on their assigned condition. Those who were not currently involved in a romantic relationship were asked to imagine that they currently had a romantic partner. The 15 scenarios were adopted from Yamaguchi et al.'s (2015) commitment signal research. Examples of each type of scenario are as follows (see the Appendix for the scenarios used in Studies 1 and 2; the scenarios used in Study 3 are reported in the 2015 paper):

High-cost commitment signal: *You called your friend/romantic partner to talk about your personal problems. Your friend/romantic partner already had a plan, but he/she cancelled the plan and kept listening to you.*

Low-cost commitment signal: *You made a big mistake at work that negatively affected many people. Your friend/romantic partner noticed that you were feeling depressed, and responded "Everyone makes mistakes."*

Commitment signal failure: *You had a personal problem with one of your social relationships, and wanted to talk about it with someone. You reached out to your friend/romantic partner, but your friend/romantic partner said "I'm in the middle of something. Let's talk about it later," and you weren't able to discuss the problem.*

After reading each scenario, participants rated (1) the extent to which each event would confirm or disconfirm the relationship bond with the partner and (2) the extent to which each event would enhance or lower trust in the partner. Ratings were collected using a 7-point scale (-3 = "strongly disconfirms bond/strongly lowers trust" to $+3$ = "strongly confirms bond/strongly enhances trust"). The 10 responses (i.e., responses to both of the above items across five scenarios) were separately aggregated for high-cost signals, low-cost signals, and signal failures (Cronbach's α = 0.87, 0.80, and 0.81, respectively).

After participants completed the vignette part of the study, loneliness was measured by the Japanese version of the Revised UCLA Loneliness scale (Moroi, 1991; Russell, 1982), which was accompanied by a 4-point scale (1 = "never feel" to 4 = "often feel"). The questionnaire also included measures of individual differences and demographic variables, however, these are not relevant to the present research (see Supplementary Materials).

2.2. Results and Discussion

We first confirmed that high-cost commitment signals (M = 2.34, SD = 0.54) were associated with a greater commitment-confirming effect than low-cost commitment signals (M = 1.27, SD = 0.50), $t(154)$ = 12.89, $p < 0.001$, Cohen's d = 2.08. We also confirmed that commitment

signal failures (i.e., a partner's failure to signal commitment despite the demands of the situation) were associated with a commitment-disconfirming effect: The mean response (-0.85, SD = 0.50) was significantly lower than the scale's neutral point of zero: $t(77)$ = 15.05, $p < 0.001$, Cohen's d = 1.70. These results replicated Yamaguchi et al.'s (2015) findings.

The average rating of participants' loneliness was 1.94 (SD = 0.47). Male participants (M = 2.06, SD = 0.43) were slightly lonelier than female participants (M = 1.87, SD = 0.49), $t(75)$ = 1.71, p = 0.09, Cohen's d = 0.39, which is consistent with previous research (see Borys & Perlman, 1985, for a meta-analytic review of sex differences in loneliness).

Contrary to Hypothesis 1a, but corroborating Hypothesis 1b, loneliness was negatively correlated with the commitment-enhancing (i.e., bond-confirming) effect of high-cost signals, r = -0.37, df = 75, $p < 0.001$ (Fig. 1a). However, for low-cost commitment signals, neither Hypothesis 1a nor 1b was supported, r = -0.13, df = 75, p = 0.26 (Fig. 1b). Therefore, Hypothesis 1b was partially supported, but Hypothesis 1a was not supported. As for signal failures, loneliness was not correlated with a commitment-disconfirming effect, r = 0.02, df = 75, p = 0.84 (Fig. 1c). Therefore, Hypothesis 2 was not supported.

As reported above, loneliness was negatively correlated with responses to high-cost commitment signals. This negative correlation remained significant even after controlling for the effects of relationship type condition, sex, and participants' current relationship status (see Supplementary Materials). Although loneliness was not correlated with responses to low-cost commitment signals, it might be attributable to weak statistical power due to a relatively small sample size (N = 78). Similarly, the non-significant correlation between loneliness and responses to a partner's failure to send a commitment signal might also be due to weak statistical power. An alternative explanation for these null effects may be associated with a range restriction in loneliness—Study 1 involved only university students. Since it is reported that loneliness is negatively correlated with education (Hawkley et al., 2008), it is possible that participants' level of loneliness in Study 1 was not representative of the greater Japanese population. Accordingly, we conducted Study 2, an internet-based replication of Study 1.

3. Study 2

3.1. Method

The purpose of Study 2 was to test the replicability of the findings of Study 1 using a larger community-based sample. Participants were recruited through an online survey service provided by Cross Marketing Inc., Japan. Although 478 Japanese participants completed the survey, 86 participants either did not follow instructions or responded to all individual differences measures with the same value (resulting in responses with zero variance). By excluding these participants, 392
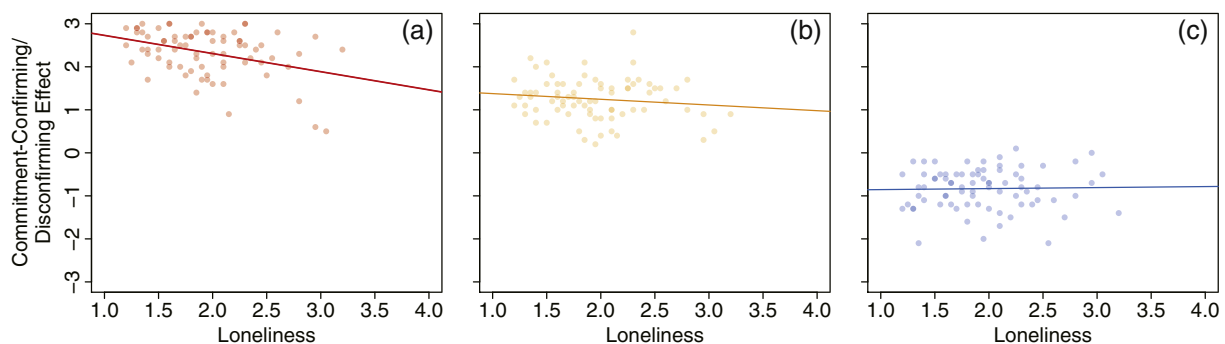

Fig. 1. The relationship between loneliness and the commitment-confirming/disconfirming effect of commitment signals in Study 1. (a) The commitment-confirming effect of high-cost signals. (b) The commitment-confirming effect of low-cost signals. (c) The commitment-disconfirming effect of a partner's failure to produce situationally appropriate commitment signals. (The darkness of each point corresponds with the number of observations at that point.)

participants were retained in the data set (195 females, 197 males, $M_{age} = 28.39$ years, $SD = 3.80$). All participants were non-students. Also, we limited this survey to unmarried people in order to provide as close an approximation as possible to the student sample in Study 1, in which all participants were single. The 2010 Japanese Population Census indicates that the proportion of unmarried men and women aged 30–34 years is 0.50 and 0.39, respectively (Statistics Bureau, the Japanese Ministry of Internal Affairs and Communications, 2011). Above this age range, unmarried rates further shrink. Accordingly, we restricted the age of the participants to 20–35 years old.

The method was similar to Study 1 with minor changes. Instead of experimentally assigning partner type (i.e., friend vs. romantic partner), participants first thought of one close (but unrelated) other, and indicated whether the person was either their friend or romantic partner. Throughout the vignette portion of the study, participants were asked to imagine that the scenarios had occurred between themselves and this close other. The number of scenarios, which were presented in random order, was reduced to twelve (i.e., four scenarios for each of the three commitment signal types) to reduce the task load of respondents who might be less familiar than university students with this type of scenario experiment. The eight responses (i.e., four scenarios × the two items) were aggregated to obtain the responses to the high-cost signal, low-cost signal, and signal failure scenarios (Cronbach's α = 0.93, 0.93, and 0.89, respectively). After the vignettes, participants completed the Japanese version of the Revised UCLA Loneliness scale, as well as some unrelated measures (see Supplementary Materials).

3.2. Results and Discussion

As in Study 1, we first confirmed Yamaguchi et al.'s (2015) results: High-cost signals ($M = 1.28$, $SD = 0.90$) were associated with a greater commitment-confirming effect than low-cost signals ($M = 0.80$. $SD = 0.78$), $t(765.29) = 7.98$, $p < 0.001$, Cohen's $d = 0.58$. The response to commitment signal failures ($M = -0.31$, $SD = 0.56$) was significantly lower than 0: $t(391) = 10.91$, $p < 0.001$, Cohen's $d = 0.55$.

In this Japanese community sample, mean loneliness ($M = 2.37$, $SD = 0.54$) was significantly higher than that of the student sample in Study 1 ($M = 1.95$, $SD = 0.47$), $t(467) = 6.42$, $p < 0.001$, Cohen's $d = 0.59$. However, variance, which is more pertinent to the range restriction problem, did not significantly differ in these two samples, $F(391, 77) = 1.30$, $p = 0.17$. Male participants ($M = 2.43$, $SD = 0.54$) reported slightly, but significantly, higher loneliness than female participants ($M = 2.30$, $SD = 0.53$), $t(390) = 2.37$, $p = 0.02$, Cohen's $d = 0.24$.

To confirm the general comparability between Studies 1 and 2, we proceeded to test our hypotheses. Consistent with Study 1, loneliness was negatively correlated with the commitment-enhancing (i.e., bond-confirming) effect of high-cost signals ($r = -0.26$, $df = 390$, $p < 0.001$; Fig. 2a). Moreover, in Study 2, loneliness was negatively correlated with the commitment-confirming effect of low-cost signals

($r = -0.29$, $df = 390$, $p < 0.001$; Fig. 2b). Accordingly, lonely individuals were less responsive to both high- and low-cost commitment signals. Therefore, Study 2 fully supported Hypothesis 1b and did not support Hypothesis 1a. However, loneliness once again was not correlated with the commitment-disconfirming effect of signal failures ($r = -0.09$, $df = 390$, $p = 0.09$; Fig. 2c). Therefore, Hypothesis 2 was not supported.

The results generally replicated the patterns observed in Study 1. Lonely individuals appear to be less moved by their partner's commitment signals than non-lonely individuals. However, lonely individuals are no more sensitive to their partner's failure to perform situationally appropriate pro-relationship behaviors. The former finding is consistent with previous research indicating that lonely individuals are hyposensitive to positive social stimuli (e.g., Hawkley et al., 2007; Vanhalst et al., 2015), whereas the latter is inconsistent with previous research indicating that lonely individuals are hypersensitive to socially threatening stimuli (J. T. Cacioppo & Hawkley, 2009). This inconsistency might arise due to cultural differences considering that most previous studies of loneliness were conducted in Western countries, whereas Studies 1 and 2 were conducted in an East Asian country (i.e., Japan). Therefore, we re-analyzed the dataset previously reported as Study 2 in Yamaguchi et al.'s (2015) article, which does not include analyses involving loneliness. Here we report this re-analysis as Study 3.

4. Study 3

4.1. Method

Participants were 534 American users of Amazon MTurk (359 females, 175 males; $M_{age} = 35.30$, $SD_{age} = 11.98$). Although Study 3 included both students and non-students, we expected that this mixed-sample would not substantially change the results because the only notable differences in the general pattern between the Japanese student (Study 1) and non-student samples (Study 2) was the lack of support for Hypothesis 1b in the low-cost signal condition which failed to reach the conventional significance-level in Study 1. Furthermore, this study did not restrict participants based upon marital status. Although we do not include marital status in our analyses reported in the main text, separate analyses for married and unmarried participants did not produce a notably different pattern of results (See Supplementary Materials).

Study 3 manipulated the signal type condition as a between-participants factor ($n = 174$, 188, and 172 in the high-cost, low-cost, and signal failure conditions, respectively). In the high-cost and low-cost commitment signal conditions, participants read three hypothetical scenarios imagining that each event really happened between themselves and an assigned close other (i.e., friend or romantic partner). In these two conditions, similar to Studies 1 and 2, responses to each scenario were measured by two items that assessed perceived bond strength
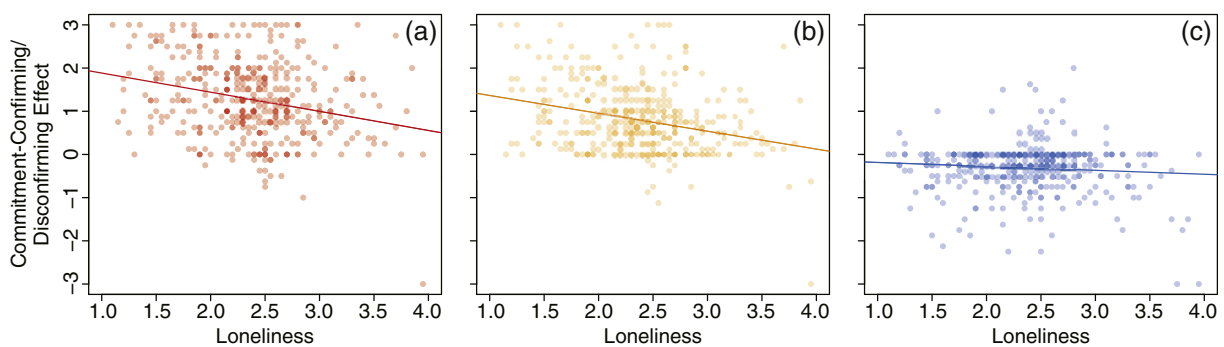
Fig. 2. The relationship between loneliness and the commitment-confirming/disconfirming effect of commitment signals in Study 2. (a) The commitment-confirming effect of high-cost signals. (b) The commitment-confirming effect of low-cost signals. (c) The commitment-disconfirming effect of a partner's failure to produce situationally appropriate commitment signals. (The darkness of each point corresponds with the number of observations at that point.)

and trustworthiness. However, instead of the 7-point scale (-3 to $+3$) used in Studies 1 and 2, these two items were accompanied by a 4-point scale ($0 =$ "strongly disagree" to $3 =$ "strongly agree"). The six responses (two items for three scenarios) were aggregated to obtain the response to high-cost and low-cost commitment signals (Cronbach's $\alpha = 0.85$ and 0.79, respectively).

In the commitment signal failure condition, participants read 11 hypothetical scenarios. After reading each scenario, participants rated how much the event would worsen the relationship with the partner. The effect of commitment signal failure was measured by a single item accompanied by a 4-point scale ($0 =$ "strongly disagree" to $3 =$ "strongly agree"). In reporting the results, we reversed the direction of participants' responses (i.e., multiplied them by -1) so that the results appear comparable with the results of the previous two studies. Confirming a sufficient reliability (Cronbach's $\alpha = 0.84$), responses to the 11 scenarios were aggregated. (See Yamaguchi et al.'s, 2015, Study 2 for more details of our method.)

4.2. Results and Discussion

The overall mean loneliness score was 2.08 ($SD = 0.54$). Replicating the gender difference observed in Studies 1 and 2, male participants ($M = 2.18$, $SD = 0.55$) were slightly, but significantly, lonelier than female participants ($M = 2.03$, $SD = 0.52$), $t(532) = 2.95$, $p < 0.001$, Cohen's $d = 0.26$. However, loneliness scores did not significantly differ across the three conditions, $F(2, 531) = 1.36$, $p = 0.26$, indicating that random assignment was successful.

When commitment signals were presented, irrespective of their costliness, lonely individuals were less responsive to the signals than non-lonely individuals: $r = -0.20$, $df = 172$, $p = 0.01$ (Fig. 3a) and $r = -0.32$, $df = 186$, $p < 0.001$ (Fig. 3b) in the high-cost and low-cost commitment signal conditions, respectively. Therefore, consistent with the previous studies, Hypothesis 1b rather than Hypothesis 1a was supported. Also, replicating the result of the previous two studies, loneliness did not predict variance in sensitivity to partners' failures to perform pro-relationship behaviors, $r = 0.04$, $df = 170$, $p = 0.60$ (Fig. 3c). Therefore, Hypothesis 2 was, once again, not supported. Because this result is consistent with Studies 1 and 2, it precludes a possible cultural explanation for why loneliness does not predict reactions to commitment signal failures.

5. General Discussion

In two new studies and one re-analysis of past data, we examined the connection between loneliness and responses to commitment signals. Previous research led us to generate two competing hypotheses regarding the effect of loneliness on reactions to commitment signals. On the one hand, it could be expected that loneliness would lead to a hypersensitivity to commitment signals, manifesting as a tendency to positively adjust the perception of interpersonal bonds in response to a partner's pro-relationship (i.e., commitment signaling) behavior (Hypothesis 1a). In this case, a heightened sensitivity to commitment could be interpreted as a compensatory mechanism allowing lonely individuals to satisfy their need for close relationships. On the other hand, some previous studies suggest that lonely individuals tend to exhibit hyposensitivity to positive social stimuli. Based on this empirical observation, it could be also expected that lonely individuals may be less sensitive to commitment signals (Hypothesis 1b). Three studies provided support for Hypothesis 1b, rather than Hypothesis 1a. This is somewhat puzzling considering that in order to reduce their aversive feeling of loneliness, lonely individuals ought to behave in a manner consistent with Hypothesis 1a, that is, to be responsive to partner commitment. Thus, the relationship between loneliness and reduced sensitivity to commitment signals is in a sense maladaptive because it diminishes the chance of maintaining satisfactory relationships.

Nevertheless, the negative correlation between loneliness and sensitivity to commitment signals must be cautiously interpreted; it might be reflective of a more general cognitive process. Clark, Loxton, and Tobin (2015) report that lonely individuals are less sensitive to rewards in general than non-lonely individuals. In particular, they showed that trait loneliness is negatively correlated with the behavioral activation system (BAS). If partners' commitment signals are represented as a reward in the brain (Izuma, Saito, & Sadato, 2008; Matsumura & Ohtsubo, 2012), the observed negative correlation between loneliness and sensitivity to commitment signals may be better accounted for by a negative correlation between loneliness and sensitivity to rewards in general. Studies 1 and 2 included the Japanese version of the BIS/BAS scale (Carver & White, 1994; Takahashi et al., 2007). However, even when the effect of reward sensitivity (measured by the BAS sub-scale) was statistically controlled for, the negative correlation between loneliness and sensitivity to commitment signals remained significant (see Supplementary Materials).

It should be noted that loneliness is associated with numerous variables other than behavioral activation. Although the questionnaires of Studies 1 and 2 included several measures of individual differences, such as the five-factor personality traits (see Supplementary Materials for details), we did not cover all possible confounding variables. For example, loneliness is often associated with low self-esteem (McWhirter, 1997; Peplau & Perlman, 1982) and depression (Cacioppo, Hughes, Waite, Hawkley & Thisted, 2006). Individuals with low self-esteem show more willingness to stay in a relationship with a partner who evaluates them unfavorably than favorably because the unfavorable appraisal matches their self-view (Swann, Hixon, & De La Ronde, 1992). Similarly, depressed individuals often seek and even prefer negative feedback from friends or romantic partners (Swann, Wenzlaff, Krull, & Pelham, 1992). Thus, in our studies, individuals with low self-esteem or high levels of depression may have discounted their partner's commitment signals because these signals, which reflect a partner's
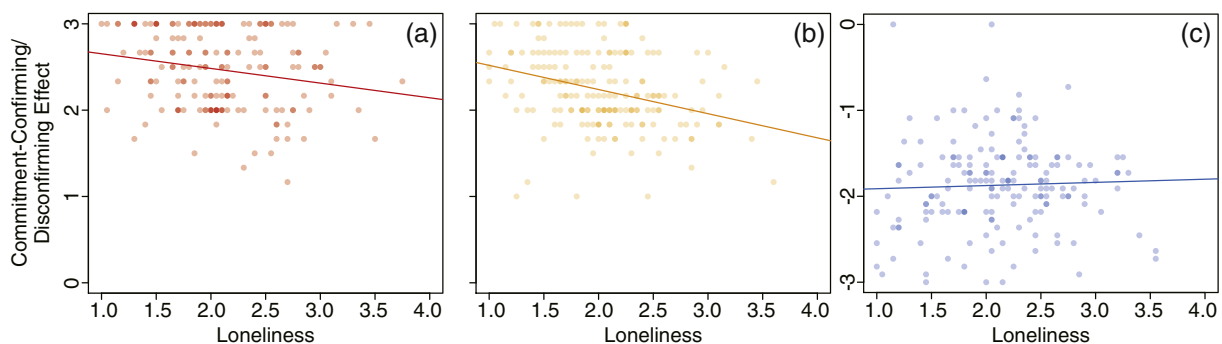

Fig. 3. The relationship between the loneliness and commitment-confirming/disconfirming effect of commitment signals in Study 3. (a) The commitment-confirming effect of high-cost signals. (b) The commitment-confirming effect of low-cost signals. (c) The commitment-disconfirming effect of a partner's failure to produce situationally appropriate commitment signals. (The darkness of each point corresponds with the number of observations at that point.)

favorable evaluation, contradict their self-perception. This explanation implies that the observed negative correlation between loneliness and sensitivity to commitment signals is a spurious correlation due to a third variable (i.e., low self-esteem or depression). Accordingly, it is reasonable to predict that lonely individuals would be hypersensitive to commitment signal failures—the conspicuous absence of a commitment signal would act as confirmation of their negative self-view. However, we did not find support for this prediction (i.e., Hypothesis 2). Nevertheless, it is important to include measures of self-esteem and depression in future studies and empirically examine whether loneliness is correlated with insensitivity to commitment signals even after controlling for these potentially confounding variables.

Given the social nature of the observed negative correlation, we still have to be cautious in interpreting the observed correlation because at least two distinct causalities are conceivable. First, the observed negative correlation could be caused by insensitivity that is specific to commitment signals. If some people are inherently less sensitive to their partners' commitment signals, they might feel lonelier because of a perceived lack of intimate relationships. Second, loneliness might diminish sensitivity to an array of positive social stimuli. Animal studies show that prolonged social isolation (e.g., being reared in an isolated cage) produces remarkable changes in the animal brain, especially in areas related to sociality (see S. Cacioppo, Capitanio, & Cacioppo, 2014, for a review). As loneliness is associated with shyness and social anxiety (e.g., Cacioppo, Hawkley, Ernst, Burleson, Bernston, Nouriani, & Spiegel, 2006; Cacioppo, Hughes, et al., 2006; Cheek & Busch, 1981), lonely individuals might avoid social interactions. If this is the case, the social functioning of lonely individuals' brains might be curtailed due to its infrequent usage. In other words, the observed negative correlation could be interpreted as a by-product of normal neurological functioning. Of course, it is difficult to determine causality in a decisive manner using only human research because it would be invasive and unethical to leave participants in a socially isolated state for a prolonged period of time. Therefore, as J. T. Cacioppo et al. (2015) maintain, studies informed by animal models are needed. Alternatively, studies incorporating behavioral strategies for overcoming loneliness (e.g., training lonely people to better attend to their partners' commitment signals) might be informative for understanding how attention to commitment signals relates to loneliness (cf. Jones, Hobbs, & Hockenbury, 1982).

The second purpose of this study was to test whether loneliness is associated with hypersensitivity to a partner's failure to send a situationally appropriate commitment signal (Hypothesis 2). This prediction was built upon previous research, which documented that lonely individuals are hypersensitive to socially threatening stimuli (e.g., Hawkley et al., 2007; Vanhalst et al., 2015). Our results, however, were somewhat surprising. Loneliness and sensitivity to a partner's failure to send situationally appropriate commitment signals were not correlated across all studies. What may explain this null finding? First, it has been shown that loneliness predicts selective attention to negative social stimuli (Bangee, Harris, Bridges, Rotenberg, & Qualter, 2014). As the present study explicitly presented negative social stimuli (i.e., the conspicuous absence of commitment signals), we may have artificially increased the salience of stimuli that would have normally been ignored by people low in loneliness. Once noticed, however, negative social stimuli might equally affect both lonely and non-lonely people. Second, our assumption that the absence of situationally appropriate pro-relationship behaviors (i.e., commitment signal failures) is a socially threatening event might be mistaken. In most of the scenarios in our study, the partner did not explicitly offend participants. If we had used more explicit offensive scenarios, we might have observed a significant correlation between loneliness and a commitment-disconfirming effect. In future studies, we need to include both implicit omission of and explicit, intentional, abstention from commitment signals.

In sum, we revealed that loneliness predicts a relative insensitivity to commitment signals. This insensitivity was observed irrespective of the costliness of the signals. However, despite our expectations, loneliness did not predict hypersensitivity to a partners' failure to produce situationally appropriate commitment signals. As stated above, in order to achieve a full-fledged understanding of how loneliness both affects and is affected by interpersonal interactions, insights from animal models and intervention trainings may prove fruitful. Considering the many adverse psychophysiological concomitants of loneliness as well as the importance of promoting healthy interpersonal relationships, we hope the present study may serve as a stimulating contribution to the loneliness literature.

Acknowledgements

Appendix A. Scenarios Used in Study 1 and Study 2

A.1. High-Cost Commitment Signal Scenarios

1. You called your friend/romantic partner to talk about your personal problems. Your friend/romantic partner already had a plan, but he/she cancelled the plan and kept listening to you.
2. You went out for dinner with your friend/romantic partner to celebrate your birthday. Your friend/romantic partner gave you a present, paid for dinner, and wished you "Happy Birthday!"
3. You planned to meet your friend/romantic partner, but you were one hour late because you overslept. When you told your friend/romantic partner that you were running late, he/she waited for you without getting angry at you.
4. You wanted to travel some places, and you invited your friend/romantic partner. Although your friend/romantic partner was quite busy, he/she did extra work to take some days off for the travel with you.
5. You told your friend/romantic partner a secret that you did not want anyone else to know about. One day, when you had a conversation with your friend/romantic partner and other friends who did not know about your secret, somebody began to talk about a topic related to your secret. Your friend/romantic partner told his/her own embarrassing episode to distract others from your secret.*

A.2. Low-Cost Commitment Signal Scenarios

1. You and your friend/romantic partner were attending night classes together in order to get an important certification. One evening, you weren't able to attend the class, but your friend/romantic partner got an extra copy of the homework to give to you.
2. You made a big mistake at work that negatively affected many people. Your friend/romantic partner noticed that you were feeling depressed, and responded, "Everyone makes mistakes."
3. You passed a certification exam. Your friend/romantic partner heard it from your acquaintance and sent an e-mail to congratulate you.
4. Your friend/romantic partner invited you to hang out together.
5. You invited your friend/romantic partner to spend time together on the weekend. Your friend/romantic partner happened to have some free time, and he/she hung out with you.*

A.3. Commitment Signal Failure Scenarios

1. You invited your friend/romantic partner to eat at a restaurant you have been interested in for some time. Your friend/romantic partner responded, "I'm busy," and you could not go to the restaurant with him/her.
2. You lost your favorite watch. But when you went to tell your friend/romantic partner about it, your friend/romantic partner simply said, "I see."

3. Someone accused you of doing something you didn't do. Your friend/romantic partner knew you were innocent, but did nothing to defend you.

4. You showed your friend/romantic partner a photo of an interesting activity you recently participated in. Your friend/romantic partner replied, "Oh, I see," and then began to show you his/her unrelated photos.

5. You had a personal problem with one of your social relationships, and wanted to talk about it with someone. You reached out to your friend/romantic partner, but your friend/romantic partner said "I'm in the middle of something. Let's talk about it later," and you weren't able to discuss the problem.*

* The fifth scenario in each category was omitted from Study 2.

Appendix B. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.paid.2016.09.047.

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