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Wendy C. Birmingham
Brigham Young University - Provo

McKenzie Carlisle

Bert N. Uchino

David M. Sanbonmatsu

Timothy W. Smith

See next page for additional authors

Authors

Wendy C. Birmingham, McKenzie Carlisle, Bert N. Uchino, David M. Sanbonmatsu, Timothy W. Smith, Matthew R. Cribbet, Kathleen C. Light, and Allison A. Vaughn

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Subliminal Activation of Social Ties Moderates Cardiovascular Reactivity during Acute Stress

McKenzie Carlisle,
Department of Psychology and Health Psychology Program, University of Utah

Bert N. Uchino,
Department of Psychology and Health Psychology Program, University of Utah

David M. Sanbonmatsu,
Department of Psychology and Health Psychology Program, University of Utah

Timothy W. Smith,
Department of Psychology and Health Psychology Program, University of Utah

Matthew R. Cribbet,
Department of Psychology and Health Psychology Program, University of Utah

Wendy Birmingham,
Department of Psychology and Health Psychology Program, University of Utah

Kathleen C. Light, and
Department of Anesthesiology and Health Psychology Program, University of Utah

Allison A. Vaughn
Department of Psychology, San Diego State University

Abstract

Objective—The quality of one's personal relationships *has* been reliably linked to important physical health outcomes, perhaps through the mechanism of physiological stress responses. Most studies of this mechanism have focused on whether more conscious interpersonal transactions influence cardiovascular reactivity. However, whether such relationships can be automatically activated in memory to influence physiological processes has not been determined. The primary aims of this study were to examine if subliminal activation of relationships could influence health-relevant physiological processes, and to examine this question in the context of a more general relationship model that incorporates both positive and negative dimensions.

Method—We randomly assigned participants to be subliminally primed with existing relationships that varied in their underlying positivity and negativity (i.e., indifferent, supportive, aversive, ambivalent). They then performed acute psychological stressors while cardiovascular and self-report measures were assessed.

Results—Priming negative relationships was associated with greater threat, lower feelings of control, and higher diastolic blood pressure reactivity during stress. Moreover, priming

Correspondence concerning this article should be addressed to McKenzie Carlisle, University of Utah, Department of Psychology, 380 S. 1530 E. Rm. 502, SLC, Utah 84112-0251, or via (mckenzie.carlisle@psych.utah.edu).

relationships high in positivity and negativity (ambivalent ties) was associated with the highest heart rate reactivity and greatest respiratory sinus arrhythmia decreases during stress. Exploratory analyses during the priming task itself suggested that the effects of negative primes on biological measures were prevalent across tasks, whereas the links to ambivalent ties was specific to the subsequent stressor task.

Conclusions—These data highlight novel mechanisms by which social ties may impact cardiovascular health, and further suggest the importance of incorporating both positivity and negativity in the study of relationships and physical health.

Social relationships are an omnipresent part of life. Importantly, supportive relationships have been reliably associated with beneficial physical health outcomes (Barth, Schneider, & von Kanel, 2010; Holt-Lunstad, Smith, & Layton, 2010; House, Landis, & Umberson, 1988). Moreover, a smaller but growing literature is consistent with the health risks associated with negative social ties (De Vogli, Chandola, & Marmot, 2007; Friedman et al., 1995). Consistent with these epidemiological literatures, positive social interactions decrease cardiovascular reactivity during stress (i.e., buffering hypothesis of support, Thorsteinsson & James, 1999), whereas negative interactions exacerbate reactivity (Ewart, Taylor, Kraemer, & Agras, 1991). These data are important because increased cardiovascular reactivity to stressors has been linked to cardiovascular disease risk (Chida & Steptoe, 2010).

Much of the prior work on relationships and physiological stress responses has examined direct social interactions (Uchino, 2009). For instance, studies have shown that the provision of social support can attenuate cardiovascular responses to stressful tasks (Lepore, 1998; Uchino, Cacioppo, & Kiecolt-Glaser, 1996), although under certain situations (e.g., Lepore, 1995; Taylor et al., 2010), received social support is not associated with reduced cardiovascular reactivity. On the other hand, perceptions of support are more consistently related to beneficial health outcomes than is received support (Barrera, 2000; Uchino, 2004). This could be because received support can convey the message that the recipient is incapable of managing difficulties on their own, thereby threatening self-esteem or perceptions of independence (Bolger, Zuckerman, & Kessler, 2000; Martire, Stephens, Druley, & Wonjo, 2002; Nadler & Fisher, 1986). Perceived support, in contrast, provides benefits without these drawbacks (Uchino, 2009). In fact, perceived and received support are at best moderately correlated and hence separable constructs (Wills & Shinar, 2000).

The role of perceptions of support, rather than the actual receipt of support, in stress buffering has been demonstrated in studies that show simply calling to mind feelings of connectedness and support can attenuate CVR to a stressor task (Ratnasingam & Bishop, 2007; Smith, Ruiz, & Uchino, 2004). For instance, Smith and colleagues (2004) used a supraliminal prime by having participants write about a supportive tie (e.g., what you appreciate about this person) or casual acquaintance and then had them perform psychological stressors. Results revealed that writing about a supportive tie was associated with lower cardiovascular reactivity to a subsequent speech stressor compared to writing about a casual acquaintance (also see Ratnasingam & Bishop, 2007).

One important question that arises from these studies is how automatic are the cognitive processes linking relationships to cardiovascular function? Given that in the studies above, no actual provision of support occurred, it is possible that subliminal (nonconscious) activation of relationship representations could impact self-regulatory processes, with subsequent implications for physiological reactivity while coping with stress. This possibility is consistent with the general view that people construct working models of their relationships with others that include self-and-other schemata (Baldwin, 1992; Ogilvie & Ashmore, 1991). Thus, activation of a relational schema could cause spreading-activation and individuals could then experience themselves in the way that they normally do when with the relationship partner even in the absence of the actual relational tie (Andersen & Berk, 1998; Baldwin, 1990).

If subliminal activation of relationship representations influences stress responses, such effects would suggest a novel and potentially far-reaching mechanism by which social relationships influence susceptibility to disease. That is, if subliminal activation of working models alters physiological stress responses, then relationship quality could influence health-relevant physiological processes well beyond circumstances involving actual or even conscious recollection of positive or negative relationship experiences. The quality of one's social life could influence pathophysiological processes and resulting health risks much more pervasively, through the myriad subtle reminders of relationships encountered during everyday experience (e.g., pictures, names). A first aim of the current study was thus to examine if subliminal activation of relationships can influence health-relevant physiological processes during stress. We focused on systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) given that these measures have been linked to significant health outcomes (Chida & Steptoe, 2010). We also examined respiratory sinus arrhythmia (RSA) as an index of vagal control of the heart. RSA is the rhythmical fluctuation in heart period occurring at the respiration band (i.e., 0.12–0.40 Hz) that is associated with a shortening and lengthening of heart periods during inspiration and expiration, respectively (Bernston, Cacioppo, & Quigley, 1993b). RSA is receiving greater attention as a health-relevant biological index associated with self-regulatory processes due to its links to prefrontal cortical areas (see Berntson et al., 1994; Thayer, Hansen, Saus-Rose, & Johnsen, 2009). Thus, if subliminal activation of relationships influences self-regulatory processes (for better or worse) than it may be closely linked to RSA (Thayer et al., 2009).

A second aim of our study was to examine these questions in the context of a more general model on the health effects of relationships (Uchino, Holt-Lunstad, Uno, & Flinders, 2001, see Figure 1). Most prior health research has focused on positive aspects of relationships. However, a growing body of literature is consistent with the deleterious health effects of negativity in relationships (De Vogli et al., 2007). Such links are generally consistent with a "negativity bias" in which such stimuli have stronger influences across various outcomes (Taylor, 1991). In addition, little research has examined the joint or interactive effects of these two common relationship experiences (Uchino, Holt-Lunstad, Uno, Campo, & Reblin, 2007). According to our model, a person falling in the high positivity/low negativity category would be a strong source of social support (e.g., the best friend you can always count on). In contrast, a network member who falls in the category of low positivity/high negativity would represent an aversive network tie (e.g., an unreasonable manager). Network members who exhibit low positivity/low negativity are people whom we come into contact with very low frequency or depth (e.g., the next-door neighbor). Relatively unique relationship ties that are salient due to this conceptual framework fall into the high positivity/high negativity category and are labeled ambivalent ties (e.g., overbearing parent, volatile romance). In our prior work, most of these network types are either family or friends, with no consistent evidence for gender differences in links between these relationship types and health outcomes (Campo et al., 2009).

In the present study, we used a subliminal priming technique to activate relationship representations related to supportive, aversive, ambivalent, and indifferent network ties. In contrast to prior work, by utilizing a subliminal priming procedure, we evaluated whether relationships that are automatically activated in memory influence reactivity, rather then due to any conscious appraisal on the part of the individual or through direct behavioral interactions. We predicted that subliminal activation of ambivalent ties would heighten cardiovascular reactivity, as would negative ties, albeit to a lesser extent. These predictions were based on the fact that ambivalent ties are sources of both positive and negative interactions, making them less predictable which has been associated with potentiated physiological responses (Uchino et al., 2007). In addition, ambivalent ties are typically described as "close," and hence there is more of an overlap between self-other representations (Aron, Aron, Tudor, & Nelson, 1991) which can exacerbate stress responses. In contrast, aversive ties are not likely to have considerable self-other overlap which should lessen any effects on self-related coping processes. These predictions are consistent with our prior work linking ambivalent ties to adverse influences on cardiovascular functioning (Holt-Lunstad, Uchino, Smith, Cerny, & Nealey-Moore, 2003; Holt-Lunstad, Uchino, Smith & Hicks, 2007; Reblin, Uchino, & Smith, 2010). We also predicted that activation of supportive ties would reduce reactivity, consistent with the buffering model and prior research on the effects of social support on physiological stress responses. Indifferent ties were expected to elicit a middle-level response, such that they should be associated with lower levels of cardiovascular reactivity than ambivalent or aversive ties, and higher reactivity than supportive ties. Finally, an exploratory aim was to examine the psychological processes that might also be related to subliminal activation of such relationships. Thus, we measured pre-task perceptions of threat, coping, and control. However, given inconsistencies between self-report and cardiovascular assessments, our primary hypotheses focused on the health-relevant measures of cardiovascular reactivity during stress (Gerin, Pieper, Levy, & Pickering, 1992).

Method

Participants and Procedures

Seventy healthy women and thirty-six healthy men (M_{age}=29.8, SD=10.94) were recruited for this study (see inclusion criteria of Cacioppo and colleagues, 1995). All participants had normal or corrected-to-normal vision and participated in a two-session study. In Session One, participants filled out informed consent and the social relationships index (SRI, see below). Participants were then randomly assigned to a supportive, ambivalent, aversive, or indifferent relationship prime condition

Within two days, participants came back for Session Two. These sessions were separated to avoid possible carry-over effects of filling out the initial SRI. Disposable spot electrodes were placed according to published guidelines (Sherwood et al., 1990) and an occluding blood pressure cuff fitted to the non-dominant arm. Following a ten-minute resting baseline in which measurements of cardiovascular function were assessed, participants completed a practice trial of the priming task, followed by the actual priming task (cf. Bargh & Pietromonaco, 1982). They then performed two stressor tasks used in prior work while cardiovascular measures were taken (i.e., a math task and speech task, see Levy et al., 2000; Uchino et al., 1992). These tasks were used because they are well documented as effective evaluative threats (Dickerson & Kemeny, 2004) and are sensitive to self-relevant subliminal manipulation (Levy et al., 2000). Prior to the tasks, measures of perceived threat, coping, and control were taken (see Gerin et al., 1995; Tomaka et al., 1997).1 The entire procedure was then repeated (i.e., priming task, math task, speech task). No significant priming effects were qualified by the type of stressor (math, speech) or time (first, second block) so analyses were performed averaging over these assessments to increase reliability (Kamarck, 1992). Lastly, participants were debriefed and compensated.

[1]At the end of the tasks, we also obtained measures of state anxiety and state self-esteem. As retrospective assessments they are likely to be less sensitive to these manipulations and predictably no effects were significant on these measures. Interested readers can contact the first authors for a copy of these analyses.

Priming Procedure—For the priming tasks, individuals were seated in front of a computer and told to focus on a "marker" (a plus (+) sign) appearing in the center of the screen. Participants were instructed to indicate as quickly and accurately as possible if a "flash" appeared above or below the marker by pressing the corresponding direction key on a keyboard (cf. Bargh & Pietromonaco, 1982; Devine, 1989; Levy et al., 2000). The priming stimuli consisted of names of individuals generated from the SRI that most represented their random assignment to relationship conditions (i.e., supportive, ambivalent, aversive, or indifferent). During this task, participants were randomly presented with 75 trials, or "flashes": twenty-five filler items, and names of up to five individuals in a particular relationship category appearing 10 times each for a total of 50 relevant name trials. The inter-trial-interval was 1000 ms. The priming stimuli were identical for both priming blocks (i.e., the same relationship names and the same filler words). The filler items were twenty-five words referring to unrelated objects, places, and events that were used to diminish the likelihood that participants would detect or recognize the presentation of the experimental stimuli or relevant names.

The priming stimulus was randomly presented for 43 ms, immediately followed by a backwards mask (Michaels & Turvey, 1979) of random upper- and lower-case letters, appearing both above and below the marker for 100 ms. Masking was employed to diminish the opportunity for the prime words to persist in the participant's visual iconic memory store (Bargh & Chartrand, 2000). The stimulus presentation time was selected on the basis of prior research (e.g., Bargh & Chartrand, 2000) and pretesting in our laboratory. However, to further ensure that the primes were subliminal, a manipulation check was administered in the main study, in which following the second priming block participants were told that the "flashes" they just saw in the prior task had actually been words; participants were then asked to write down any words they may have seen and were told that they were welcome to guess.

Assessments

Cardiovascular Measures—A Dinamap Model 100 was used to measure SBP and DBP. The Dinamap uses the occillometric method to calculate blood pressure. Blood pressure assessments were obtained using a properly sized occluding cuff positioned on the upper left arm of the participant according to manufacturer‘s specifications. Mean SBP and DBP for each epoch (i.e., baseline, primes, stressors) were averaged across minutes to increase the reliability of these assessments (Kamarck, 1992).

A Mindware 2000D Module was used to measure the ECG which was also used to calculate RSA.[2] Seven spot-electrodes were placed according to manufacturer and published guidelines (Hoetink et al., 2002; Sherwood et al., 1990). The ECG was digitized at 1000 Hz and each waveform was verified or edited prior to analyses. Respiratory sinus arrhythmia (RSA) provided a noninvasive measure of parasympathetic control of the heart and was calculated based on the digitized inter-beat intervals that were checked and edited for artifacts using the detection algorithm of Bernston, Quigley, Jang, & Boysen (1990). Following linear de-trending (Bernston, Cacioppo, & Quigley, 1995; Litvack, Oberlander, Carney, & Saul, 1995), the heart-period time series was band-pass-filtered from 0.12 to 0.40 Hz (Neuvo, Cheng-Yu, & Mitra, 1984). The power spectrum of heart-period time series was calculated using a Fast Fourier Transform and scaled to ms^2/Hz. RSA was calculated as the natural log of the area under the heart-period power spectrum within the corner frequencies

[2]We also collected impedance-derived assessments of cardiac output, total peripheral resistance, and pre-ejection period. However, we encountered high rates of missing data for the dZ/dt signal which is used to calculate these measures and thus did not have significant power to look at these assessments. Exploratory analyses of these variables predictably showed no group differences.

of the band-pass filter (Litvack et al., 1995). RSA was calculated on a minute-by-minute basis and aggregated across minutes within each epoch to increase measurement reliability.

Social Relationship Index (SRI)—The SRI instructs individuals to list significant other, parents, and then ten “other” family members, friends, co-workers, and social acquaintances. These network members are rated in terms of how helpful and upsetting they are on a 1 (not at all) to 6 (extremely) point scale. The SRI allows an operationalization of different categories of social relationships as primary sources of positivity (i.e., supportive), primary sources of negativity (i.e., aversive), sources of relatively high positivity and negativity (i.e., ambivalent), or low levels of positivity and negativity (i.e., indifferent). Selection criteria based on the relationship categories was such that we started by searching for the purest form of that assigned category (e.g., a supportive tie requires a "6" on the helpful rating and a "1" on the upsetting rating). Because we were interested in relative differences between these relationship types, if no “pure” form of that tie was found, then we looked for the next closest rating to the purest form. However, each relationship type had a threshold at which a tie would no longer be considered for a specific category. For supportive ties, the lowest a tie could be rated was a "4" on helpful and a "1" on upsetting whereas for ambivalent ties the lowest helpful rating was a "4" and lowest upsetting rating was a "2." In comparison, the lowest upset rating for aversive ties was a "3", with the highest helpful rating a "2." For indifferent ties, the highest helpful and upset ratings allowed were "2." The main reasons for allowing lower minimum upset ratings for these classifications (compared to helpfulness ratings) were (a) the lower negativity rating typically endorsed for social ties and (b) its strong influence even at such lower levels (Campo et al., 2009; Taylor, 1991). Prior work has shown that these network measures were temporally stable with significant three-month test-retest correlations (see Campo et al., 2009). The range of unique priming names for the different conditions were as follows: 5 names for the supportive condition (44% family, 43% friends, 13% co-workers), 3–5 names for the ambivalent condition (54% family, 37% friends, 9% co-workers), 3–4 names for the aversive condition (43% family, 27% friends, 30% co-workers), and 2–5 names for the indifferent condition (40% family, 35% friends, 25% co-workers).

Appraisals and Perceived Control—Prior to each math and speech task, participants completed a measure of challenge and threat appraisals utilized by Tomaka, Blascovich, Kibler, & Ernst (1997). Participants were asked to rate on a 6-point Likert scale “how threatening do you expect the task to be” and “how able are you to cope with the task”. They also were asked “How much control do you feel you have over this task” on a 10-point Likert scale (Gerin, Litt, Deich, & Pickering, 1995).

Results

Manipulation Checks and Preliminary Analyses

Priming Manipulation Awareness—Participants were given a brief recall task following the 2nd set of primes. Consistent with our piloting, less than 1% of primes were correctly recalled which is well below current guidelines for subliminal priming research (5%, Bargh & Chartrand, 2000). This did not differ significantly as a function of our experimental conditions and deleting individuals who reported at least one correct prime did not alter the pattern of findings reported below.

Positivity/Negativity Ratings—To verify our relative relationship category manipulations, we ran separate tests for average helpful (positivity) and upset (negativity) ratings of the primed ties. A 2 (Positive Primes: low, high) X 2 (Negative Primes: low, high) ANOVA was used as it allows a simultaneous test of our model (interactions) and prior work that has examined relationship positivity and negativity in isolation from each other (main effects). These analyses revealed the expected main effects of positive primes on helpfulness ratings and negative primes on upset ratings (p's < .001). Finally, there were significant positive primes X negative primes interactions on both helpfulness and upset ratings (p's < .01). In these interactions, individuals who were in the low negative / high positive condition (supportive) had the highest helpful ratings, whereas individuals in the low positive / high negative condition (aversive) had the highest upset ratings.

Does Subliminal Priming of Relationships Influence Cardiovascular Reactivity?

Our main cardiovascular analysis was based on reactivity scores (stressor task minus baseline) while also statistically controlling for baseline levels. Preliminary analyses revealed no significant priming effects that differed by gender. A series of 2 (Positive Primes) X 2 (Negative Primes) ANCOVAs revealed a main effect for negative primes on DBP reactivity, $F(1, 97) = 3.95$, $\eta^2 = .04$, $p < .05$, such that participants primed with relationships entailing high negativity had greater DBP reactivity during the stressor tasks ($LSM_{high} = 7.74$ versus $LSM_{low} = 5.76$, a similar trend on SBP reactivity was also evident, p=.07). No positivity main effects were found on any of the cardiovascular reactivity assessments (p's > .28, see Table 1).

Consistent with our predictions, significant positive X negative primes interactions emerged for HR ($F(1, 92) = 5.54$, $\eta^2 = .06$, $p < .05$) and RSA ($F(1, 93) = 3.82$, $\eta^2 = .04$, $p = .05$) changes during stress. More specifically, individuals primed with ambivalent relationship ties had the highest average HR changes during stress (see Figure 2, top panel) and greatest decrease in RSA consistent with exaggerated parasympathetic withdrawal during stress (bottom panel). Follow-up comparisons revealed that HR and RSA reactivity in the group primed with ambivalent ties was significantly greater than that of supportive (p=.01 and p=.03, respectively) and even aversive (p=.02 and p=.08, respectively) ties. In fact, consistent with RSA representing parasympathetic influences on the heart, subsequent analyses showed that it mediated the association between relationship primes and HR reactivity (see Baron & Kenny, 1986). That is, there was as significant independent effect of RSA change on HR change, $F(1, 90) = 32.92$, $p < .01$, and the previously significant interaction on HR reactivity was rendered non-significant (p = .12) when controlling for RSA reactivity (sobel test of t=1.90, p=.03, one-tailed).

What are the effects of Subliminal Relationship Primes on Self-Report Psychological Processes?

Pre-task measures of threat, coping, and control were also analyzed. Significant main effects of negative primes were found on perceived threat, $F(1, 97) = 11.66$, $\eta^2 = .12$, $p < .01$, and control, $F(1, 97) = 4.21$, $\eta^2 = .04$, $p < .05$. In these main effects, participants primed with high negative ties had greater perceptions of threat and lower perceptions of control towards the stressor tasks. However, exploratory analyses of whether these psychological processes statistically mediated the negative primes main effect on DBP did not reveal any evidence to this point. No other main effects or interactions were significant. Thus, consistent with prior social psychophysiological work, there was an uncoupling between self-reported psychological states and cardiovascular changes during stress (e.g., Gerin et al., 1992).

Ancillary analyses of cardiovascular change during the priming task

We also collected physiological measures during the priming task itself. However, many individuals finished in less than 2 minutes so there were less cardiovascular measures taken during this period which would negatively influence its reliability (Kamarck, 1992). We thus considered these analyses more exploratory. These analyses revealed that negative relationship primes were associated with increased SBP, $F(1, 97) = 7.42$, $\eta^2 = .02$, $p < .01$, and DBP, $F(1, 97) = 3.93$, $\eta^2 = .01$, $p = .05$, reactivity during the priming task itself. In addition, there was a marginally significant positive primes main effect on SBP reactivity during the priming task, $F(1, 97) = 3.21$, $p = .08$, indicating lower reactivity with high positive primes. No other effects approached significance. Thus, the negative primes main effect was present throughout both the priming and stressor tasks, whereas the ambivalence links were only present during the stressor task.

Discussion

Prior work on social relationships and cardiovascular function has demonstrated the benefits of positive social support and detriments of negative relationships on health (Berkman, 1995; De Vogli et al., 2007; Friedman et al., 1995). However, little is currently known about the levels of processing or relative influence of positive and negative aspects of relationships that might link them to physical health outcomes. This is the first study we know of that shows subliminal activation of relationship representations can alter cardiovascular functioning.

Our first main finding was that high negative primes were associated with greater blood pressure reactivity across both the priming and stressor tasks. These data are consistent with a negativity bias in which such stimuli elicit stronger responses compared to positive stimuli (see Cacioppo & Bernston, 1994; Taylor, 1991). This effect has previously been shown in the relationship literature in which "not being nasty matters more than being nice" in terms of blood pressure reactivity (Ewart et al., 1991). Our data further suggest that this bias is prevalent even at a non-conscious level. The uniformity of the links between negative relationships and different levels of processing may account for the deleterious influences of negative social ties across health outcomes.

Although exploratory analyses did reveal a marginally significant effect during the priming task, one important question is why weren't we able to find stronger effects for positive or supportive ties given prior links to health? One explanation is that positive relationship primes may have made social evaluation more salient which could off-set any stress-buffering influences because individuals care about how these ties view them (Taylor et al., 2010). Another possibility is that positivity (support) may require more conscious processing to have physiological benefit as all studies that we are aware of showing beneficial main effects of social support on physiological processes used supraliminal, or more explicit manipulations of provided support. This is salient because supraliminal vs. subliminal priming rely on different neurological substrates (Koulder, Dehaene, Jobert, & Le Bihan, 2007). Finally, it is important to note that we chose "helpful" as the positive dimension for our relationship assessment as it corresponds more closely to the social support literature. However, it is possible that had we used a broader assessment of positivity (e.g., how positive in general) we may have found stronger effects for the positive primes. Future research will be needed to evaluate these possibilities. Nevertheless, these data are consistent with recent research suggesting that when both positivity and negativity in relationships are assessed, negativity exerts more powerful influences on health outcomes (De Vogli et al., 2007).

Consistent with our predictions, we did find evidence that priming ambivalent ties was associated with greater HR; an effect that was mediated by RSA changes during stress. The lack of findings specifically for ambivalent ties during the priming task itself is also potentially interesting because it is consistent with our prior work suggesting that ambivalent ties are associated with increased reactivity primarily in a negative (stressful) context (Holt-Lunstad et al., 2007; Reblin, Uchino, & Smith, 2010). As a result, two interpretations of these findings are possible. First, Thayer and colleagues (2009) propose that measures of cardiac vagal tone (e.g., RSA) quantify a person's capacity to self-regulate. If RSA is a unitary dimension, then decreases in RSA should be associated with decreased self-regulation as it has been linked to less activation of the prefrontal cortex which may impair self-regulatory processes (Thayer et al., 2009). Applied to the current study, participants primed with ambivalent ties may be showing a self-regulatory deficit during stress. A second possible interpretation of our findings is based on Porges' Polyvagal Theory (2007), where a decrease in RSA occurs in response to a threatening environment (i.e., fight/flight response). This would indicate that ambivalent primes activate biological systems that deal with threats, where the first action would be to let up on the quicker parasympathetic "brake" to confront stressful events. Future research will be aimed at evaluating these possibilities.

These data more generally highlight the importance of a joint consideration of positive and negative aspects of relationships. Prior work has typically examined positive or negative aspects of relationships in isolation; a practice which may obscure reliable associations based on these different relationship types (Uchino et al., 2007). We believe ambivalent ties to be of particular importance because they are not an isolated feature of most individuals' social networks, hence they have ample opportunity to influence health-relevant social processes. In fact, our prior work suggests that ambivalent ties are unique predictors of greater cardiovascular reactivity during direct social interactions in the laboratory (Holt-Lunstad et al., 2007; Reblin et al., 2010) and everyday life (Holt-Lunstad et al., 2003). The current work extends our understanding by linking ambivalent ties to cardiovascular outcomes at non-conscious levels of processing.

It is also interesting that negative primes exerted their influence more on blood pressure, whereas ambivalent primes had more specific effects on cardiac chronotropic measures (i.e., time-based linked to heart rate). The specific reasons for these patterns are unclear but worthy of discussion. Although both of these patterns may reflect health-relevant cardiovascular changes, the findings for HR and RSA suggest that ambivalent primes may have had an influence more through central-peripheral self-regulatory processes (Thayer et al., 2009). Consistent with this possibility, despite their co-occurring negativity, ambivalent ties are typically rated as "close" (Holt-Lunstad et al., 2007) which is likely to reflect an overlap of self-other representations (Aron et al., 1991). Thus, activating ambivalent ties may result in spreading activation with more direct influence on self-relevant processes. On the other hand, there is relatively less specificity in terms of blood pressure responses, suggesting that negative primes may have had an influence through more general mechanisms often associated with negative stimuli (Taylor, 1991). Future research aimed at evaluating the implications of these more specific patterns will be needed.

There are several limitations of our study. First, because we were interested in testing the relative effects of relationships in our model, we did not include a non-social (or non-emotional) priming control group. Thus, it is unclear if these findings are unique to relationship processes. There are conceptual reasons to suspect that relationships may be particularly powerful as priming stimuli due to overlaps in self-other representations (cf. Aron et al., 1991). However, future work is needed in order to determine whether it is the activation of a social schema, or simply the valence of the prime, that is influencing these outcomes. Second, although cardiovascular reactivity has been linked to future mortality (Chida & Steptoe, 2010), expanding our outcomes to other health-relevant physiological assessments (e.g, inflammation) would provide converging evidence for our findings. Another potential limitation of our study is that we did not control respiration rate or depth. However, RSA is often not highly susceptible to such artifacts within many behavioral contexts and "corrected" and "uncorrected" RSA are often highly correlated (Denver, Reed, & Porges, 2007; Grossman, Beek, & Wienties, 1990; Kotani, Tachibana, & Takamasu, 2007). Finally, we did not find evidence for the self-reported psychological processes by which priming relationships influenced cardiovascular function. These results are consistent with the uncoupling that can occur between self-report and physiological processes (e.g., Gerin et al., 1992) and highlights the importance of data from different levels of analysis (Cacioppo & Petty, 1986). However, recent research is emphasizing links between physiology and more specific emotional processes (e.g., social emotions, Dickerson & Kemeny, 2004) and may be particularly important for future research in this area.

The limitations of this study notwithstanding, one additional mechanism linking relationships to health outcomes appears to be related to the activation of internal representations of individuals in our social networks. The current findings are important, in that mental representations of relationships appear to influence individuals in the absence of actual interpersonal interactions. From photographs around the home (Baldwin, 1990), to a familiar name on a billboard (Baldwin, 1994) or meeting someone new (Andersen & Baum, 1994), our everyday lives are filled with potential stimuli for non-conscious activation of mental representations of relationships. Our results open a novel research domain to examine the physical costs and benefits of conscious vs. non-conscious activation of relational schemata, which can inform contemporary theories linking relationships to physical health outcomes.

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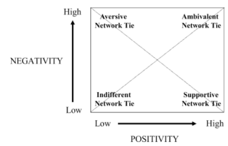

Figure 1.
A general framework for examining positive and negative aspects of relationships on health.

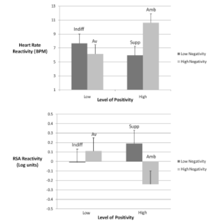

Figure 2.

Relationship positivity and negativity interaction means for heart rate (top panel) and RSA (bottom panel) changes during stress (i.e., stress tasks minus baseline). Note: Indiff=Indifferent ties, Av=Aversive ties, Supp=Supportive ties, Amb=Ambivalent ties.

Table 1

Least squares means and standard deviations for major dependent variables.

	Relationship Type			
Variable	**Indifferent**	**Supportive**	**Ambivalent**	**Aversive**
Resting				
SBP (mmHg)	115.96 (11.16)	114.23 (11.17)	111.1 (8.75)	112.36 (10.7)
DBP (mmHg)	72.83 (8.09)	71.66 (7.94)	69.43 (5.72)	70.4 (5.45)
HR (BPM)	73.48 (11.08)	72.58 (11.46)	73.23 (10.98)	73.92 (9.79)
RSA (log)	6.27 (1.2)	6.13 (1.5)	6.42 (1.1)	6.38 (1.29)
Reactivity				
SBP (mmHg)	11.74 (6.8)	11.33 (6.76)	13.08 (6.8)	14.93 (6.76)
DBP (mmHg)	6.03 (4.98)	5.48 (4.95)	7.47 (4.98)	8.0 (4.95)
HR (BPM)	7.66 (6.44)	5.96 (6.45)	10.61 (6.44)	6.14 (6.44)
RSA (log)	−0.01 (0.7)	0.19 (0.7)	−0.24 (0.7)	0.11 (0.7)
Threat	2.25 (0.98)	2.13 (0.88)	2.74 (0.98)	2.91 (0.85)
Control	8.17 (1.84)	7.72 (1.77)	6.87 (2.14)	7.48 (1.71)
Coping	5.0 (1.0)	5.16 (0.78)	4.88 (0.76)	4.83 (0.71)

Note. Reactivity scores calculated as stress task levels minus resting levels.