Emotion
2016, Vol. 16, No. 1, 83–93

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1528-3542/16/$12.00 http://dx.doi.org/10.1037/emo0000105

Sharing the Burden: The Interpersonal Regulation of Emotional Arousal in Mother–Daughter Dyads

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According to social baseline theory (Beckes & Coan, 2011), load sharing is a feature of close relationships whereby the burden of emotional distress is distributed across relationship partners. Load sharing varies by physical closeness and relationship quality. We investigated the effect of load sharing on emotional arousal via galvanic skin response, an indicator of sympathetic nervous system arousal, during a social stressor. Social stress was elicited in 66 adolescent girls (M_{age} = 15 years) using a spontaneous public-speaking task. Mother–daughter dyads reported their relationship quality, and physical closeness was manipulated by having mothers either touch or not touch their daughter's hand during the performance. We found evidence of load sharing among dyads who held hands, independent of relationship quality. However, without physical contact, load sharing was only evident among dyads with higher relationship quality. Thus, high relationship quality buffers against threat in a similar way to the physical comfort of a loved one.

Keywords: mother–daughter interactions, adolescence, interpersonal emotion regulation, social stress

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Decades of research has indicated that social relationships are crucial for mental and physical health (Holt-Lunstad, Smith, & Layton, 2010). Not only do positive (i.e., stable, supportive, and satisfying) social relationships have indirect salutary effects on health, but they also have been causally linked to a lower likelihood of mortality (Holt-Lunstad et al., 2010; House, Landis, & Umberson, 1988). However, according to social baseline theory (SBT; Beckes & Coan, 2011), positive relationships may not confer psychological and physical benefits. Rather, a lack of or distance from significant others leads to negative mental and physical health outcomes (Beckes & Coan, 2011). Thus, positive social relationships are the norm, and deviations from that baseline (e.g., a lack of sufficient relationships or the presence of negative relationships) drive the associations between relationships and psychosocial outcomes (Beckes & Coan, 2011).

The main tenet of SBT is that humans evolved to be in close proximity to other humans (Beckes & Coan, 2011). Group living is an evolutionary adaptation that leads to survival through efficient energy management and the conservation of resources, because living in close proximity to others distributes the burden of tasks that lead to survival (e.g., vigilance for predators, self-regulation) among members of the group (Roberts, 1996). There is evidence that social relationships have been central to the evolution of resource conservation mechanisms (Beckes & Coan, 2011). For example, individuals are more likely to succeed if challenges are perceived as less threatening, and physical closeness to another person, especially a trusted relationship partner, decreases perceived threat in challenging situations (Schnall, Harber, Stefanucci, & Proffitt, 2008).

One mechanism through which social relationships lead to energy conservation is the process of *load sharing* (Beckes & Coan, 2011). Load sharing involves distribution of the burden associated with challenging situations (e.g., emotional distress) across relationship partners (Ehrenberg, Gearing-Small, Hunter, & Small, 2001). Load sharing can be instrumental or psychological (Beckes & Coan, 2011). An example of instrumental load sharing is when family members share the burden of household chores. An example of emotional load sharing—the focus of the current study—is when a mother helps her daughter to manage her stress by offering some form of comfort. In this example of emotional load sharing, the comfort offered by the mother reduces the amount of energy expended by the daughter in managing her own stress, and thus regulation would be more efficient. Load sharing implies that close relationship partners are extensions of each other and that individuals' interactions with the world are embedded within social systems (Beckes & Coan, 2011). Isolated individuals therefore experience greater demands on their own psychological resources, such as when self-regulating emotion and behavior (Schnall et al., 2008).

Interpersonal Emotion Regulation

Under threatening circumstances, it is necessary for individuals to regulate emotions to overcome challenges (Thompson, 1994).

This article was published Online First August 31, 2015.

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Supported by the Natural Sciences and Engineering Research Council of Canada (Grant 386479-2011).

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Emotion regulation refers to processes that increase, decrease, or otherwise change the occurrence, intensity, or temporal profile of emotions (Thompson, 1994). Interpersonal emotion regulation, specifically, refers to both the up- and down-regulation of emotions through social interactions, in which individuals' emotions are connected to and affected by the emotions of their interaction partner (Butler, 2011; Thompson, 1994). Emotions are inherently social signals to others that, among many things, communicate needs and potential threats (Campos, Walle, Dahl, & Main, 2011). Load sharing allows emotional strain to be distributed across relationship partners, which prevents ego depletion (i.e., a reduction in self-control observed among individuals following effortful self-regulation; Baumeister, Bratslavsky, Muraven, & Tice, 1998) and thereby conserves resources required for effective emotion regulation (Beckes & Coan, 2011; Fitzsimons & Finkel, 2011). Thus, load sharing can be considered a form of interpersonal emotion regulation. Distance from relationship partners places a greater demand on emotion regulation resources than when close relationship partners are present to influence and regulate each others' emotions (Butler, 2011; Fitzsimons & Finkel, 2011; Hughes, Crowell, Uyeji, & Coan, 2012).

The ability to regulate emotions develops in an interpersonal context (Fogel, 1993; Kopp, 1989). Close relationship partners (e.g., primary caregivers) support children of all ages in threatening, stressful situations, and provide emotional scaffolding that helps children internalize their own abilities to manage emotions under stress (Kopp, 1989; Morris, Silk, Steinberg, Myers, & Robinson, 2007). The role of the parent–child relationship in shaping children's emotion regulation goes beyond parental socialization via modeling and scaffolding. Parent–child dyads are a temporal interpersonal emotion system (TIES), in which the subcomponents of both parents' and children's emotion systems (e.g., physiological arousal) are directly linked in time to each others' (Butler, 2011; Crowell et al., 2014). That is, parent–child dyads are a dynamic system in which emotions are coconstructed and regulated interpersonally (Granic, 2005). The parent–child TIES emerges through repeated interpersonal interactions, in which emotions are mutually regulated in real time, and developmentally, long-standing interpersonal patterns emerge (Fogel, 1993). Two examples of interpersonal emotion regulation in TIES are *emotion transmission* (one partner's arousal predicts their partner's arousal at a subsequent point in time) and *attenuation* (the influence of one partner on their partner's decrease in arousal over time; Butler, 2011).

Interpersonal Regulation of Sympathetic Nervous System Activity

One component of emotional responding is sympathetic nervous system (SNS) activity, which is triggered during threatening situations and is associated with stress and anxiety (Crowell et al., 2005; Kreibig, 2010). SNS arousal plays a role in sensitivity to interpersonal challenges, and interpersonal emotional reactivity and regulation (Diamond & Cribbet, 2013). SNS arousal increases during socially stressful situations, such as giving a speech in front of a stranger (Eastabrook, Lanteigne, & Hollenstein, 2013), and both SNS arousal and recovery are positively associated with affiliation (e.g., behavioral warmth) in mother–adolescent interactions (Diamond & Cribbet, 2013; Willemen, Schuengel, & Koot, 2009). SNS arousal is regulated in part through social interactions, and individuals who experience loneliness (i.e., a lack of sufficient social relationships) have difficulties with regulation, as indicated by chronically elevated SNS arousal (Cacioppo, Hawkley, & Berntson, 2003). In addition, it is common for individuals to seek social interactions when SNS arousal is high as a means of decreasing SNS arousal (Taylor, 2006). Load sharing may therefore be one mechanism in the social regulation of SNS arousal because SNS arousal is most often reactivity to threat, and the regulation of threat is thought to be the evolutionary origin of load sharing (Beckes & Coan, 2011; Coan & Sbarra, 2015). Although there is an emerging body of research on dyadic psychophysiological processes (e.g., Connell, Hughes-Scalise, Klostermann, & Azem, 2011; Crowell et al., 2014; Ferrer & Helm, 2013; Reed, Randall, Post, & Butler, 2013), the hypothesis that load sharing would be reflected in interpersonal SNS response patterns has not yet been tested.

Interpersonal Emotion Regulation in Adolescence

During adolescence, individuals are particularly sensitive to social stress (Westenberg, Drewes, Goedhart, Siebelink, & Treffers, 2004), because adolescence involves the formation of novel social bonds with peers and the transformation of family relationships (Smetana, Campione-Barr, & Metzger, 2006). More generally, adolescence is a period of intense psychological, biological, and social changes, accompanied by more intense emotions (Hollenstein & Lougheed, 2013). This places adolescents at an increased risk for psychosocial adjustment difficulties, and emotion regulation is an important contributor to adolescent well-being (McLaughlin, Hatzenbuehler, Mennin, & Nolen-Hoeksema, 2011).

Interpersonal emotion regulation via load sharing in caregiver–adolescent TIES (Butler, 2011; Crowell et al., 2014) may be essential to typically developing adolescents' responses to social threats because of the role played by caregivers in the socialization of emotion regulation from childhood through adolescence (Morris et al., 2007). Load sharing can occur through either physical closeness or relationship closeness (i.e., relationship quality) to significant others (Beckes & Coan, 2011; Schnall et al., 2008). For example, either distance from a close relationship partner or lower subjective relationship quality may lead to increased arousal under stress (Coan, Schaefer, & Davidson, 2006; Coan, Kasle, Jackson, Schaefer, & Davidson, 2013; Schnall et al., 2008). Indeed, physical closeness and relationship quality may interact, with emotional load sharing being most effective when high levels of relationship quality and physical closeness combine (Coan et al., 2006). Although load sharing is an interpersonal process, much of the research to date has examined it in terms of attenuated threat responses within the individual who is experiencing stress (e.g., Coan et al., 2006; Coan et al., 2013). It is unknown how individuals respond when they are sharing load of another's distress, which is an important aspect when examining interpersonal processes in TIES (Butler, 2011). Thus, in the current study, we examined both physical closeness and relationship quality with respect to mothers' sharing of their adolescent daughters' emotional load through decreases in daughters' arousal and associations between daughters' and mothers' arousal during adolescent social stress.

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The Current Study

We examined emotional load sharing during an adolescent-targeted social stressor, by examining physiological arousal of the SNS using galvanic skin response (GSR; Boucsein, 2012). GSR is a measure of electrodermal changes due to SNS activity, and is associated with anxiety and stress responses in adolescents and adults (Boucsein, 2012; Crowell et al., 2005; Kreibig, 2010). The social stressor was a spontaneous speech task in which daughters were instructed to give a speech on a topic of their choice in front of an experimenter. We manipulated physical closeness during the speech task by randomly assigning mother−daughter dyads to either (a) touch hands during the speech task (mothers kept their hand atop their daughter's hand; *touch* condition) or (b) not to touch each other during the speech task (*no touch* condition). Mother−daughter dyads were the focus because adolescent females share more with their parents and are more emotionally expressive than males (Collins & Russell, 1991; Perry-Parrish & Zeman, 2011).

The objective was to examine load sharing—the shared burden of emotion regulation as a function of both physical closeness and relationship quality—in terms interpersonal emotion processes. Evidence of maternal load sharing of adolescent stress can be observed in different ways: lower average levels of adolescent arousal, interpersonal influences on arousal dampening, and greater decreases in adolescent arousal over time at higher mother−daughter physical closeness and relationship quality. First, we examined maternal load sharing of adolescent arousal in terms of overall levels of arousal, with lower adolescent arousal at higher physical closeness and relationship quality providing evidence of load sharing (Coan et al., 2006). Second, we examined load sharing in terms of *arousal transmission*, the extent to which one's emotional arousal influences the arousal of another person over time (Butler, 2011). Arousal transmission occurs in situations that elicit empathy, such as seeing a family member in a stressful situation (Goubert, Vervoort, Sullivan, Verhoeven, & Crombez, 2008; Reed et al., 2013). Arousal transmission refers to positive covariation between interaction partners' emotions (Reed et al., 2013). Arousal transmission can occur in two directions, one being the transmission of arousal amplification (e.g., a mother's and daughter's stress levels mutually amplify each others') and the other being the transmission of arousal dampening (e.g., a daughter's stress level decreases through interacting with her mother who feels a lower level of stress, resulting in mutual dampening of arousal over time). Load sharing can be observed in the transmission of arousal dampening. The transmission of arousal dampening reflects the synchronized emotional responses indicative of load sharing because the social regulation of emotion decreases the perception of threat among relationship partners (Beckes & Coan, 2011). Third, we examined load sharing in terms of the influence of the mother on adolescents' *arousal attenuation*, the extent to which arousal decreased over time during the socially stressful task as a function of touch and relationship quality.

We hypothesized that greater physical closeness and relationship quality would be associated with lower average levels of adolescent arousal, the mother-to-daughter transmission of arousal dampening, and more efficient adolescent arousal attenuation (i.e., a steeper decrease in arousal over time during the stressful task). We also hypothesized that physical closeness and relationship quality would interact, such that load sharing (lower arousal, the interpersonal transmission of arousal dampening, and more efficient arousal attenuation) would be greatest when both physical proximity and relationship quality were combined (among dyads with higher relationship quality in the touch condition). Finally, because the current study is the first study to date to examine the physiological responding of the individual sharing the load of the individual under stress, we also examined mothers' physiological responses as they shared the load of their daughters' stress. Because SBT posits that psychological load sharing functions to decrease the *perception* of threat (Beckes & Coan, 2011), we expected to find that greater physical closeness and relationship quality would not be associated with differences between conditions on mothers' average levels of arousal, daughter-to-mother arousal transmission, and mother arousal attenuation.

Method

Participants

Participants were a community sample of 66 typically developing adolescent females ages 14.03−16.88 years (M = 15.15 years, SD = 0.79) and their mothers. Mothers' ages ranged from 32.98−54.98 years (M = 45.88 years, SD = 4.34). Participants were recruited via telephone from the participant database maintained by the developmental area of the Department of Psychology at Queen's University in Southern Ontario, and through posters in community and online locations such as malls, libraries, and Facebook. Approximately 59% of families had a gross family income greater than $100,000 (Canadian) per year, 15% had an income between $75,000 and $100,000 per year, 14% had an income between $40,000 and $75,000 per year, 6% had an income between $25,000 and $40,000 per year, and 5% had an income less than $25,000 per year. Mothers reported their marital status as married (82%), divorced (8%), living with a domestic partner (6%), single (3%), and separated (1%). Mothers identified their own ethnicities as European Canadian (83%), other (11%), Central/South American (3%), and First Nations (3%). Mothers identified their daughters' ethnicities as European Canadian (82%), other (15%), and First Nations (3%). Mother and daughter participants received $15 each for participating.

Procedure

Mothers and daughters attended a laboratory session where they first received a letter of information and provided informed consent. Participants were seated in comfortable chairs beside each other in an observation room equipped with obscured video cameras and physiological recording equipment that were monitored from an adjacent room. A female experimenter familiarized participants with the general procedures of the study and the physiological recording equipment before participants filled out a series of questionnaires online. Questionnaires pertained to demographics and relationship quality.

Next, physiological sensors were applied to participants by female experimenters. To measure sympathetic physiological arousal by GSR, an SS3 electrodermal response transducer (Biopac Systems Inc., 2007) was attached to the tips of the middle and ring fingers on one hand of each participant. GSR was re-

corded continuously from an MP150 amplifier (Biopac Systems Inc., 2007) at 200 Hz and was calculated as level of conductance in micromhos. Heart rate and respiration were also measured but were not analyzed as part of the current study because they are not direct indicators of SNS activity.

Once physiological sensors were recording, participants were instructed to either touch hands by having the mother place her hand on her daughter's (touch condition; $n = 34$) or to ensure they were not touching during the remainder of the session (no touch condition; $n = 32$). Next, to obtain a baseline arousal measure, participants sat quietly while watching a neutral nature film clip for approximately 2.5 min to measure participants' normal resting physiological states. After the baseline phase, social stress was elicited using a speech task, in which adolescents were instructed to make a 3-min speech on any topic as if in front of classmates at school. Mothers in both conditions were instructed to be silent during the speech task. At the end of the lab session, all participants were debriefed.

Measures

Questionnaires. In addition to responding to a questionnaire regarding demographics, mothers and daughters completed a questionnaire regarding relationship quality.

Relationship quality. We assessed relationship quality using a measure developed by Beazer (1998) based on three separate scales assessing relationship quality (Cicirelli, 1980; Esposito, 1995; Risman & Park, 1988). Mothers and daughters each responded to eight items (e.g., "How much do you feel that you can turn to your mother/daughter when you are in need of help or guidance?"; "In general, how close to you feel to your mother/daughter?") on a 7-point scale (1 = *not at all* and 7 = *very, very much* or *very, very close*). Internal consistency of the mean across all items was good for mothers ($\alpha = .88$) and daughters ($\alpha = .92$). Mothers' and daughters' relationship quality scores were moderately, positively correlated ($r = .35$, $p = .01$). We formed a dyadic measure of relationship quality by calculating the mean of mothers' and daughters' scores in order to examine load sharing with respect to the overall level of relationship quality, rather than with respect to individuals' perceptions of the relationship separately for mothers and daughters.

Laboratory measures. Laboratory measures were physiological recordings that occurred during baseline and speech tasks.

Baseline arousal. GSR was recorded continuously during the baseline task. GSR data were smoothed at a sampling rate of 1000 Hz to yield a continuous measure with the AcqKnowledge 4.2 software package (AcqKnowledge, 2011). Average GSR values were calculated separately for mothers and daughters.

Arousal during speech. To examine load sharing of physiological arousal, mothers' and daughters' fluctuations in GSR were measured continuously during the speech task. To prepare physiological arousal data for analysis, the Acq*Knowledge* 4.2 software package (Acq*Knowledge*, 2011) was used to process GSR time-series data. Smoothed GSR data were exported into 5-s epochs, because latencies for electrodermal responses can range up to 5 s (Boucsein, 2012). Each of the 35 epoch values was the mean GSR value for those 5 s. Finally, to control for individual differences in baseline GSR and to facilitate interpretation across participants, we calculated the percent change from baseline for all epochs (Boucsein, 2012; Eastabrook et al., 2013; Swan et al., 2007). Specifically, each individual's baseline GSR mean was subtracted from their GSR mean for each 5-s epoch of the speech task, and the result was divided by their baseline GSR mean. Thus, a value of zero on GSR percent change indicated a speech response equal to an individual's own baseline, whereas negative values indicated decreases in GSR and positive values increases in GSR from a person's baseline GSR mean.

Results

Preliminary Analyses

Data from three dyads were excluded from analyses due to technical problems that resulted in missing or unusable physiological data. All variables were inspected for normality of distributions, univariate outliers, and missing values. Relationship quality was negatively skewed so a square root transformation was applied prior to conducting preliminary analyses. Dyads (with at least one member) with extreme values greater than 3.5 *SD* from the sample mean on variables were excluded from analyses to prevent outliers from exerting undue influence on the results ($n = 2$). Thus, analyses reported below are based on 61 dyads (touch $n = 31$; no touch $n = 30$). For comparison, results of analyses using the full sample are reported in footnotes (below) where the results differed.

Table 1 shows the means and standard deviations for relationship quality, baseline mother arousal, and baseline daughter arousal. Independent-samples *t* tests comparing dyads in the touch and no touch conditions on mean relationship quality, and baseline GSR among adolescents revealed no significant differences between conditions ($ts < 1.13$, $ps > .27$). A significant difference was found for baseline GSR level among mothers, $t(59) = -2.09$, $p = .041$.[1] The main analyses (see Model 1 description and Model 2 description) were run on percent change from baseline scores to account for individual differences in baseline GSR arousal levels and therefore to overcome issues associated with mean level differences between conditions on mothers' baseline GSR arousal levels. On average, daughters showed significantly higher GSR percent change from baseline during the speech task than mothers, $t(59) = -10.36$, $p < .01$, which indicates that the speech task was successful as an adolescent-focused stressor.

Physical Closeness, Relationship Quality, and Arousal Levels and Transmission

Model 1 description. We used multilevel modeling to examine the effects of physical closeness and relationship quality on arousal levels and interpersonal transmission of emotional arousal. Specifically, we used two-level models for distinguishable dyads, in which measures (5-s epochs) at Level 1 were nested within dyads at Level 2 (Bolger & Laurenceau, 2013). This approach simultaneously estimates separate parameters for each member of the dyad and allows modeling of within-dyad processes, such as arousal transmission. An unstructured covariance matrix was used in model estimation. In Model 1, we examined the extent to which

[1] This difference was marginally significant when the outliers were included in the analysis, $t(61) = -1.96$, $p = .06$.

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Table 1
Means (Standard Deviations) of Relationship Quality, and Baseline Mother and Daughter Arousal

Variable	No touch	Touch	Total
Relationship quality	5.98 (0.63)	5.93 (0.57)	5.95 (0.59)
Baseline mother arousal	2.34 (1.71)	3.28 (1.79)	2.82 (1.80)
Baseline daughter arousal	4.90 (1.19)	5.39 (2.12)	5.15 (1.73)

Note. Raw values reported.

dyadic partners' arousal levels (i.e., GSR) predicted each other over time. In this model, an individual's arousal level at time T (i.e., the current 5-s epoch) was modeled as a function of her partner's arousal level at time $T - 1$ (i.e., the previous 5-s epoch) using a cross-lagged regression approach. Following Bolger and Laurenceau (2013), we estimated separate intercepts and slopes for mothers (denoted by the subscript $_M$) and daughters (denoted by the subscript $_D$), as shown below:

$$\text{Level 1}: \text{Arousal}_{Ti} = \pi_{0Mi} + \pi_{0Di} + \pi_{1Mi}(\text{daughter's arousal}_{T-1i}) + \pi_{1Di}(\text{mother's arousal}_{T-1i}) + e_{Ti}$$

$$\text{Level 2}: \pi_{0Mi} = \beta_{00M} + \beta_{01M}(\text{condition}_i) + \beta_{02M}(\text{relationship quality}_i) + \beta_{03M}(\text{Condition} * \text{Relationship Quality}_i) + r_{0Mi}$$

$$\pi_{0Di} = \beta_{00D} + \beta_{01D}(\text{condition}_i) + \beta_{02D}(\text{relationship quality}_i) + \beta_{03D}(\text{Condition} * \text{Relationship Quality}_i) + r_{0Di}$$

$$\pi_{1Mi} = \beta_{10M} + \beta_{11M}(\text{condition}_i) + \beta_{12M}(\text{relationship quality}_i) + \beta_{13M}(\text{Condition} * \text{Relationship Quality}_i) + r_{1Mi}$$

$$\pi_{1Di} = \beta_{10D} + \beta_{11D}(\text{condition}_i) + \beta_{12D}(\text{relationship quality}_i) + \beta_{13D}(\text{Condition} * \text{Relationship Quality}_i) + r_{1Di}$$

At Level 1, the outcome (arousal_{ti}) was a "stacked" variable reflecting each person in dyad i's arousal level at time T (the variable was stacked because mothers' and daughters' values are in a single data column on top of each other; see Bolger & Laurenceau, 2013). The outcome was modeled as a function of two random intercepts (π_{0Mi} and π_{0Di}) and two random slopes (π_{1Mi} and π_{1Di}). The Level 1 slopes reflect the cross-lagged association between each person's arousal level at time T and their partner's arousal level at time $T - 1$, and therefore represent the transmission of physiological arousal. Specifically, the Level 1 slope (π_{1Mi}) reflects the association between a mother's current arousal level and her daughter's arousal level 5 s earlier, for dyad i. Similarly, the Level 1 slope (π_{1Di}) reflects the association between a daughter's current arousal level and her mother's arousal level during the previous 5-s interval, for dyad i. The cross-lagged predictors (Daughter's/Mother's $\text{Arousal}_{T\text{-}5i}$) were person-mean centered, such that they reflect deviations from each individual's mean level (note that centering was done at the person level rather than at the dyad level; see Bolger & Laurenceau, 2013). Due to centering of the cross-lagged predictors, the Level 1 intercepts (π_{0Mi} and π_{0Di}) reflect the average levels of arousal for mothers and daughters in each dyad i, respectively.

At Level 2, the Level 1 intercepts and slopes were allowed to vary randomly across dyads and were modeled as a function of condition (0 = *no touch* and 1 = *touch*) and relationship quality (standardized across dyads). Thus, for mothers, β_{00M} is the estimated mean level of arousal in the no touch condition at an average level of relationship quality, β_{01M} represents the effect of touch condition (i.e., the difference between touch and no touch conditions) on the mean level of arousal, β_{02M} reflects the association between relationship quality and the mean level of arousal in the no touch condition, and β_{03M} is the Condition × Relationship Quality interaction on the mean level of arousal (i.e., the difference between touch and no touch conditions in terms of the association between relationship quality and mean arousal). The Level 2 parameters β_{00D}, β_{01D}, β_{02D}, and β_{03D} are the corresponding estimates for daughters.

Furthermore, at Level 2, β_{10M} represents the average arousal transmission slope for mothers (i.e., the association between a mother's current arousal level and her daughter's arousal 5 s earlier, or daughter-to-mother arousal transmission) in the no touch condition at the average level of relationship quality. β_{11M} represents the difference between conditions in daughter-to-mother arousal transmission at the mean level of relationship quality. β_{12M} represents the association between relationship quality and daughter-to-mother arousal transmission in the no touch condition. Finally, β_{13M} represents the Condition × Relationship Quality interaction on the daughter-to-mother arousal transmission slope. The Level 2 parameters β_{10D}, β_{11D}, β_{12D}, and β_{13D} are the corresponding estimates for daughters.

Model 1 results. Model 1 examined mean-level differences and cross-lagged correlations of mother and daughter arousal (arousal transmission).

Mothers' mean level of arousal. Parameter estimates for mean-level differences in mothers' arousal are shown in Table 2. As expected, the nonsignificant parameter estimates for β_{01M}, β_{02M}, and β_{03M} indicated that, for mothers, the mean level of arousal did not vary by condition, relationship quality, or their interaction.

Daughters' mean level of arousal. Parameter estimates for mean-level differences in daughters' arousal are shown in Table 2. The positive, significant parameter estimate for β_{03D} indicated that the effect of condition on mean level of arousal varied by relationship quality[2] (see Figure 1a). This significant interaction was followed up with a simple slopes analysis. Contrary to expectations, the slope for the touch condition was not significant, indicating that, in the touch condition, daughters' mean level of arousal did not vary by relationship quality. However, the slope for the no touch condition was significant ($\beta = -0.14$, $SE = 0.06$, $p = .03$, 95% confidence interval [CI] [−0.26, −0.02]), indicating that, in the no touch condition, relationship quality was significantly, negatively related to mean level of arousal.

Daughter-to-mother arousal transmission. Parameter estimates for the cross-lagged influence of daughter arousal on mother arousal are shown in Table 2. There was evidence for significant daughter-to-mother arousal transmission, on average (see β_{10M}).

[2] This effect was in the same direction, but no longer statistically significant when outliers were included in the analysis, $\beta_{03D} = 0.22$, $SE = 0.14$, $p = .12$, 95% confidence interval [−0.05, 0.49].

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Table 2
Fixed-Effect Estimates From the Multilevel Model 1 Examining Mean-Level Differences and Cross-Lagged Correlations of Mother and Daughter Arousal (Arousal Transmission)

	Mean level				Cross-lagged correlation (arousal transmission)			
Outcome	Parameter	Estimate (*SE*)	*p*	95% CI	Parameter	Estimate (*SE*)	*p*	95% CI
Mother Arousal	Intercept, β_{00M}	0.72 (0.17)	<.001	[0.39, 1.05]	Intercept, β_{10M}	0.54 (0.25)	.04	[0.05, 1.03]
	Condition, β_{01M}	−0.29 (0.21)	.16	[−0.70, 0.12]	Condition, β_{11M}	0.27 (0.60)	.65	[−0.91, 1.45]
	RQ, β_{02M}	−0.06 (0.10)	.53	[−0.26, 0.14]	RQ, β_{12M}	−0.06 (0.20)	.75	[−0.45, .33]
	Condition × RQ, β_{03M}	−0.06 (0.12)	.62	[−0.30, 0.18]	Condition × RQ, β_{13M}	0.35 (0.35)	.32	[−0.34, 1.04]
Daughter Arousal	Intercept, β_{00D}	0.64 (0.07)	<.001	[0.50, 0.78]	Intercept, β_{10D}	0.58 (0.18)	<.01	[0.23, 0.93]
	Condition, β_{01D}	−0.25 (0.12)	.04	[−0.49, −0.01]	Condition, β_{11D}	−0.02 (0.21)	.92	[−0.43, 0.39]
	RQ, β_{02D}	−0.14 (0.06)	.03	[−0.26, −0.02]	RQ, β_{12D}	0.44 (0.14)	<.01	[0.17, 0.71]
	Condition × RQ, β_{03D}	0.17 (0.08)	.05	[0.01, 0.33]	Condition × RQ, β_{13D}	−0.34 (0.18)	.06	[−0.69, 0.01]

Note. No touch coded 0 and touch coded 1. Approximate $df = 57$. CI = confidence interval; RQ = relationship quality.

However, the nonsignificant parameter estimates for β_{11M}, β_{12M}, and β_{13M} indicated that daughter-to-mother arousal transmission did not vary by condition, relationship quality, or their interaction.

Mother-to-daughter arousal transmission. Parameter estimates for the influence of mother arousal on daughter arousal are shown in Table 2. There was a marginally significant ($p = .06$) Condition × Relationship Quality interaction (β_{13D}).[3] Due to the exploratory nature of this study, this marginally significant interaction was followed up with a simple slopes analysis to facilitate interpretation. Figure 1b plots the association between relationship quality and mother-to-daughter arousal transmission separately for each condition. Contrary to expectations, the simple slope for touch condition was not significant, indicating that among dyads who made physical contact during the stressor, mother-to-daughter arousal transmission (the extent to which mothers' arousal predicted daughters' arousal) did not vary by relationship quality. In contrast, mother-to-daughter arousal transmission was significantly associated with relationship quality in the no touch condition, with higher relationship quality being associated with greater mother-to-daughter arousal transmission ($\beta = 0.44$, $SE = 0.14$, $p < .01$, 95% CI [0.17, 0.71]).[4] Thus, in the no touch condition, mothers' arousal more strongly predicted daughters' arousal at higher levels of relationship quality. Regarding effect sizes, condition and relationship quality accounted for 10% of the between-dyad variance in cross-lagged slopes, and adding the interaction increased the variance accounted for to 13%.

Physical Closeness, Relationship Quality, and Arousal Attenuation

Model 2 description. A second multilevel model was used to examine the effects of physical closeness and relationship quality on the attenuation of physiological arousal over the course of the speech task. Specifically, we estimated change over time in mothers' and daughters' arousal using a linear growth model at Level 1. Model 2 was otherwise equivalent to Model 1 reported above. The equation for Level 1 was:

$$\text{Arousal}_{Ti} = \pi_{0Mi} + \pi_{0Di} + \pi_{1Mi}(\text{time}_{Ti}) + \pi_{1Di}(\text{time}_{Ti}) + e_{Ti}$$

At Level 1, the outcome (arousal_{Ti}) represents person *i*'s arousal at time *T* as a function of two random intercepts (π_{0Mi} and π_{0Di}) and two random slopes (π_{1Mi} and π_{1Di}), reflecting the linear effect of time for mothers and daughters, respectively. The time variable ranged from 0 (*start of the speech task*) to 1 (*end of the speech task*), with equally spaced intervals for intervening observations. Thus, the Level 1 intercepts (π_{0Mi} and π_{0Di}) reflect the level of arousal at the beginning of the speech task for mothers and daughters, respectively. The Level 1 slopes are the linear effects of time for mothers' arousal and daughters' arousal and, therefore, represent change in arousal over time, with negative slopes indicating arousal attenuation. The Level 1 slope (π_{1Mi}) represents the change in mothers' arousal over time, for dyad *i*. Similarly, the Level 1 slope (π_{1Di}) represents the change in daughters' arousal over time, for dyad *i*. At Level 2, the Level 1 intercepts and slopes were allowed to vary randomly across dyads and were modeled as a function of condition (0 = *no touch* and 1 = to*u*ch) and relationship quality (standardized across dyads). Thus, for mothers, β_{00M} is the estimated level of arousal at the beginning of the speech task in the no touch condition at the average level of relationship quality, β_{01m} represents the effect of the touch condition (i.e., the difference between the touch vs. no touch conditions), β_{02M} reflects the association between relationship quality and the level of arousal at the beginning of the speech task in the no touch condition, and β_{03m} is the interaction between condition and relationship quality on the level of arousal (i.e., the difference between touch and no touch conditions in terms of the association between relationship quality and level of arousal) at the beginning of the speech task. The Level 2 parameters β_{00D}, β_{01D}, β_{02D}, and β_{03D} are the corresponding estimates for daughters.

At Level 2, β_{10M} represents mothers' change in arousal over time among dyads in the no touch condition at the average level of relationship quality (Level 1 slope π_{1Mi}). β_{11M} represents the effect of the touch condition (i.e., the difference between the touch and no touch conditions) on mothers' change in arousal over time at the average level of relationship quality. β_{12M} is the effect of relationship quality on mothers' change in arousal over time for

[3] This interaction was statistically significant when outliers were included in analyses ($\beta_{13D} = -0.36$, $SE = 0.17$, $p = .04$, 95% confidence interval [−0.69, −0.03]).

[4] When outliers were included in the analyses, simple slopes were significant for both touch ($\beta = 0.14$, $SE = 0.07$, $p = .04$, 95% confidence interval [CI] [0.00, 0.28]) and no touch ($\beta = 0.50$, $SE = 0.16$, $p < .01$, 95% CI [0.19, 0.81]) conditions.

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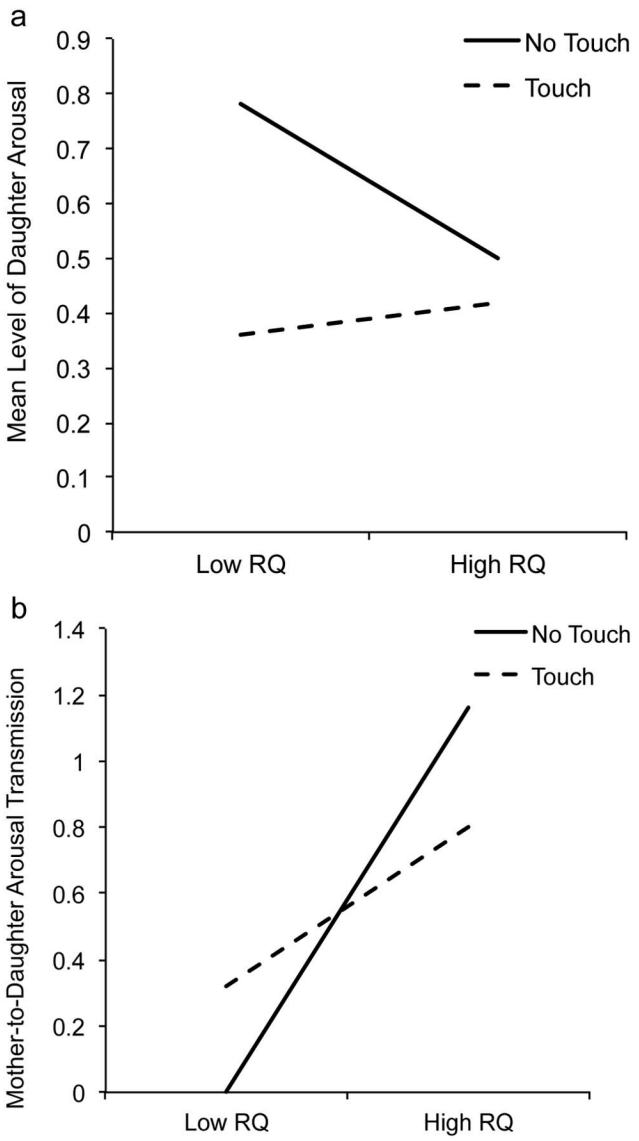


Figure 1. Condition × Relationship Quality interaction on the mean level of daughter arousal (a), and Condition × Relationship Quality interaction on mother-to-daughter arousal transmission (b). RQ = relationship quality.

the no touch condition. Finally, β_{13M} is the difference between conditions in terms of the association between relationship quality and mothers' change in arousal over time. The Level 2 parameters β_{10D}, β_{11D}, β_{12D}, and β_{13D} are the corresponding estimates for daughters.

Model 2 results. Model 2 examined arousal change over time (linear time slope) of mother and daughter arousal during the speech task.

Mother arousal attenuation. Parameter estimates for the linear time trend of mother arousal are shown in Table 3. Mother arousal at the start of the speech task did not vary by condition, relationship quality, or their interaction. Regarding arousal attenuation, in line with expectations, the nonsignificant parameter estimate for β_{10M} indicated that in the no touch condition, mothers' arousal did not change significantly over the course of the speech task. Also in line with expectations, the nonsignificant parameter estimate for β_{11M} indicated that the touch condition did not differ from the no touch condition in terms of mothers' change in arousal over time. Similarly, the nonsignificant parameter estimates for β_{12M} and β_{13M} indicated that mothers' change in arousal over time did not vary by relationship quality or the Condition × Relationship Quality interaction, respectively.

Daughter arousal attenuation. Parameter estimates for the linear time trend of daughters' arousal are shown in Table 3. In line with expectations, the significant parameter estimate for β_{01D} indicated that daughters' arousal was lower at the beginning of the speech task in the touch condition than the no touch condition. Regarding arousal attenuation, the interaction between condition and relationship quality (β_{13D}) was significant. We followed this up with a simple slopes analysis, which revealed that among dyads in the touch condition, daughters' change in arousal over time did not vary significantly by relationship quality ($\beta = 0.02$, $SE = 0.03$, $p = .47$, 95% CI [−0.04, 0.08]). In contrast, among dyads in the no touch condition, daughters' arousal was significantly related to relationship quality, such that arousal decreased more steeply over time at higher levels of relationship quality ($\beta = -0.12$, $SE = 0.05$, $p = .03$, 95% CI [−0.22, −0.02]). Figure 2 displays linear time slopes reflecting daughters' arousal attenuation separately for each condition and for high (+1 *SD*) versus low (–1 *SD*) levels of relationship quality. Regarding effect sizes, condition and relationship quality accounted for 1% of the between-dyad variance in the linear time slopes, and adding the interaction increased the variance accounted for to 7%.

Discussion

The current study is the first examination of physiological processes in both partners during load sharing (the daughter who experienced stress and the mother who shared the load). Previous research on the effects of physical closeness on stress responses has only measured outcomes in terms of the individual targeted by the threat (Beckes & Coan, 2011; Coan, Beckes, & Allen, 2013; Coan, Kasle, et al., 2013; Coan et al., 2006; Conner et al., 2012). As expected, physical closeness was associated with lower adolescent arousal, but contrary to expectations, mother-to-daughter transmission of arousal dampening and adolescent arousal attenuation did not vary by physical closeness alone. Higher relationship quality was associated with lower adolescent arousal, higher mother-to-daughter transmission of arousal dampening, and larger decreases in adolescent arousal over time, as expected. Most strikingly, the finding that the effects of relationship quality were stronger in the no touch condition than the touch condition goes against prior research that has shown an additive effect of relationship quality and physical closeness on stress responses (Coan et al., 2006). Instead, the current findings suggest that relationship quality is more strongly related to maternal load sharing of daughters' stress when mothers and daughters are unable to be in physical contact with each other.

Relationship Quality and Physical Closeness

Rather than an additive effect of relationship quality and physical closeness, we found that, without physical contact, load shar-

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Table 3
Fixed-Effect Estimates From the Multilevel Model 2 Examining Arousal Change Over Time (Linear Time Slope) of Mother and Daughter Arousal During the Speech Task

	Arousal at start of speech task				Arousal attenuation (linear time slope)			
Outcome	Parameter	Estimate (*SE*)	*p*	95% CI	Parameter	Estimate (*SE*)	*p*	95% CI
Mother	Intercept, β_{00M}	0.73 (0.16)	<.001	[0.42, 1.04]	Intercept, β_{10M}	−0.02 (0.08)	.79	[−0.18, 0.14]
	Condition, β_{01M}	−0.20 (0.23)	.38	[−0.65, 0.25]	Condition, β_{11M}	−0.17 (0.12)	.16	[−0.41, 0.07]
	RQ, β_{02M}	−0.05 (0.10)	.62	[−0.25, 0.15]	RQ, β_{12M}	−0.03 (0.15)	.59	[−0.32, 0.26]
	Condition × RQ, β_{03M}	−0.04 (0.13)	.75	[−0.29, 0.21]	Condition × RQ, β_{13M}	−0.03 (0.07)	.58	[−0.17, 0.11]
Daughter	Intercept, β_{00D}	0.75 (0.09)	<.001	[0.57, 0.93]	Intercept, β_{10D}	−0.22 (0.05)	<.001	[−0.31, −0.12]
	Condition, β_{01D}	−0.24 (0.14)	.01	[−0.51, 0.03]	Condition, β_{11D}	0.00 (0.06)	.96	[−0.12, 0.12]
	RQ, β_{02D}	−0.07 (0.07)	.34	[−0.21, 0.07]	RQ, β_{12D}	−0.12 (0.05)	.03	[−0.22, −0.02]
	Condition × RQ, β_{03D}	0.09 (0.10)	.38	[−0.11, 0.29]	Condition × RQ, β_{13D}	0.14 (0.06)	.03	[0.02, 0.26]

Note. No touch coded 0 and touch coded 1. Approximate $df = 57$. CI = confidence interval; RQ = relationship quality.

ing was observed only among dyads with higher relationship quality. Specifically, daughter arousal, mother-to-daughter arousal transmission, and daughters' arousal attenuation over time varied by relationship quality in the no touch condition, but not significantly so in the touch condition. These results may indicate that physical closeness to mothers functioned as a relationship cue to all daughters in the current sample. In other words, regardless of the quality of their relationship with their mothers, feeling the comfort of physical closeness reminded daughters that they were not alone in managing the stressful experience. As a caveat to this interpretation, we note that average relationship quality was relatively high and variability in relationship quality was quite limited in the current sample. Nevertheless, daughters with relatively low relationship quality in the touch condition may have been cued to the availability of support by the touch of their mother, which they otherwise may not have presumed to be available. In contrast, daughters in the no touch condition with relatively low relationship quality did not benefit from the supportiveness cue of physical contact and, consequently, they were less able to efficiently manage their stress (i.e., their load was not shared). Although the current findings for mother-to-daughter arousal transmission should be interpreted with caution, because the relevant interaction effect was just above the conventional *p* less than .05 cutoff, these findings suggest that high relationship quality may buffer against threat similarly to the physical comfort of a loved one.

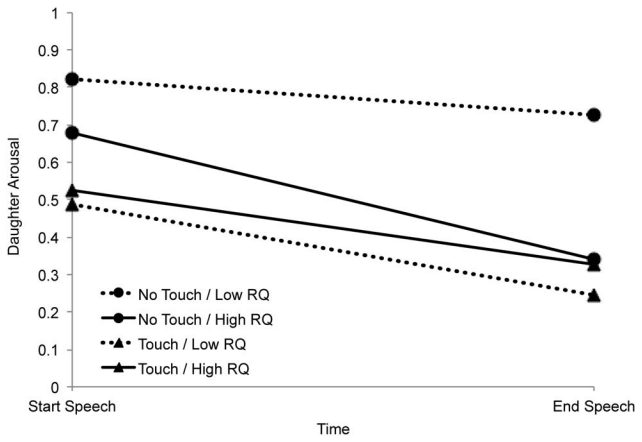


Figure 2. Condition × Relationship Quality interaction on the change in daughter arousal over time (daughter arousal attenuation). RQ = relationship quality.

Another possible explanation for the lack of additive effects of relationship quality and physical closeness is that the regulatory processes in mother−daughter relationships differ from regulatory processes in romantic relationships, the relationship context in which previous research has shown an additive effect (Coan et al., 2006). Primary caregiving relationships are typically the first relational context in which emotions are social

Load Sharing and Maternal Arousal

The influence of mothers' arousal on daughters' arousal, in the context of lower adolescent arousal and more efficient arousal attenuation, represents the distribution of adolescents' emotional response in a close mother−daughter relationship. Although we found that maternal load sharing of daughters' emotions did not influence maternal SNS activity (i.e., mothers' arousal, daughter-to-mother arousal transmission, and arousal attenuation did not vary by physical closeness, relationship quality, or their interaction), we did find that mothers' arousal was linked to daughters' arousal. Thus, as suggested by SBT (Beckes & Coan, 2011), load sharing likely functions by decreasing the perceptions of threat in the individual experiencing stress, rather than the load sharing partner literally taking on some of the emotional load (i.e., showing increases in arousal). However, as we observed mother-to-daughter transmission of arousal dampening at higher levels of physical closeness and relationship quality, the emotional state of the load-sharing partner does play a role in how emotional loads are shared between close relationship partners.

Load Sharing in Temporal Interpersonal Emotion Systems

Moment-to-moment interpersonal processes stabilize over time into enduring patterns (e.g., dyadic tendencies) and relationship characteristics such as relationship quality (Butler, 2011; Granic, 2005; Lichtwarck-Aschoff, Kunnen, & van Geert, 2010). Individual emotions are situated in a broader, interpersonal context comprised of others' emotions across the life span (Butler, 2011; Fogel, 1993; Thompson, 1994). One person's emotions emerge not

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only from the temporal coordination of their own emotion response (e.g., physiological arousal in response to a threat), but also from the emotion responses of others (Butler, 2011; Crowell et al., 2014; Ferrer & Helm, 2013). Thus, emotions are regulated interpersonally in TIES, in which individuals' emotions are linked to their partners' (Butler, 2011). In the current study, mother−daughter TIES were observed in the real-time influence of mother arousal on daughter arousal. In the absence of physical contact, relationship closeness forged a link between mothers' and daughters' emotions in real time. In this manner, high relationship quality had the same buffering effect as physical closeness—being in a high-quality relationship is akin to feeling a relationship partner's touch during a stressful encounter. While this was observed in the current study for adolescent daughters in relation to their mothers, further research is needed to examine to what extent this generalizes to other forms of TIES (e.g., romantic couples, friends).

Results also suggest that the negative emotion regulation outcomes associated with lower relationship quality (Beckes & Coan, 2011) can be overcome by physical contact. Physical closeness to relationship partners elicits biological processes associated with feelings of safety and well-being, such as the release of oxytocin (Matthiesen, Ransjö-Arvidson, Nissen, & Uvnäs-Moberg, 2001) and decreased neural responses to threat (Conner et al., 2012). These hormonal and neural responses may be other bases of TIES. The perceived reliability of relationship partners is important for load sharing—individuals in relationships characterized by unresponsiveness and low support rely more on their own self-regulation capacity in challenging situations and, therefore, have a relative deficit of resources (Beckes & Coan, 2011; Fitzsimons & Finkel, 2011), except, perhaps, when a relationship cue is present, such as physical contact.

Taken together, the results of the current study provide support both for the TIES model (Butler, 2011) and for SBT (Beckes & Coan, 2011). Emotions are inherently social, and emotions are regulated interpersonally (Campos et al., 2011). Interpersonal emotion regulation occurs through the temporal linking of close relationship partners' emotions (Butler, 2011). To examine human emotion and emotion regulation as primarily individual-level processes is to decontextualize humans from the social environment to which we have adapted through evolution (Beckes & Coan, 2011). Thus, an interpersonal approach is necessary for the study of optimal emotion and emotion regulation, because individuals isolated from the social context function at a relative deficit (Beckes & Coan, 2011).

Limitations and Future Directions

When interpreting the results of the current study, it is important to note several features of the sample: the average level of relationship quality and socioeconomic status were high, and only mother−daughter dyads were examined. Future research is needed to examine load-sharing processes at lower levels of relationship quality. Because emotion regulation varies by socioeconomic status (Raver, 2004), load sharing should be also examined in samples that are more diverse. In addition, because emotion, its regulation, and its socialization vary by sex (Collins & Russell, 1991; Perry-Parrish & Zeman, 2011), future research should examine if load sharing differs in other parent–child dyads types. The load-sharing processes examined in the current study may also not generalize to other types of close relationships (e.g., romantic partners, close friends). Another limitation of the current study was the relatively small sample size. The presence of two outliers (one extreme high outlier on maternal GSR, one extreme low outlier on mother−daughter relationship quality) in this relatively small sample influenced the results of the study, as seen in the differences in the results with and without these outliers. We examined the data for these two dyads and found that in one dyad, the mother had relatively high depression symptoms, and in the other dyad, the daughter had relatively high social anxiety symptoms. Thus, it is possible that these two dyads differ significantly from the majority of the sample based on normative internalizing symptomatology. Further research is needed to better examine load-sharing processes in dyads across a broader range of psychosocial functioning. It is possible, for example, that dyads with elevated levels of depression would share their emotional loads less than nondepressed dyads (Crowell et al., 2014).

The current study examined load sharing in the context of one component of the emotion system, the physiological SNS arousal as indexed by electrodermal activity. TIES consist of interactions among all components of the emotion system (Butler, 2011), which includes emotional experiences and expressions in addition to physiological arousal (Hollenstein & Lanteigne, 2014). An important direction for future research is to examine concordance among emotion system components, both within individuals and the TIES of which they are a part, during load sharing with close relationship partners. Examining the complex relations between concordance at the individual level as well as the dyadic level during interpersonal emotion regulation will clarify emotion regulation mechanisms.

Conclusion

The current study demonstrates that the temporal dynamics of emotional arousal are subject to load sharing in a dyadic context. In line with SBT, emotional load sharing is a function of physical closeness, and, at greater physical distance, relationship quality. Thus, high relationship quality buffers against threat in a way similar to the physical comfort of a loved one. Sharing the burden of emotional distress is one benefit of close relationships.

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Received March 4, 2015
Revision received June 15, 2015
Accepted June 22, 2015 ■

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