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Prolonged marital stress is associated with short-lived responses to positive stimuli

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Abstract

Marital stress is associated with a higher incidence of psychiatric disorders, in particular major depression. One pathway through which marital stress may impact emotional health is by compromising emotion-responding processes. We examined a longitudinal sample of adults ($N = 116$; 59 males; 39–84 years) to verify how marital stress predicts reactivity to, and recovery from, emotional provocation. Individuals watched positive, neutral, and negative pictures while an objective measure of affective state, corrugator supercilii muscle activity, was recorded continuously. Our results indicate that marital stress is associated with short-lived responses to positive pictures, indexed by a less persistent decrease in corrugator activity after picture offset. Extending beyond the prior focus on negative emotional processes, these results suggest that social stress may impact health by influencing the time course of responding to positive events.

Descriptors: Marital stress, Positive affect, Corrugator supercilii, Facial electromyography

Interpersonal relationships, and their failure, powerfully influence our mood (Bolger, DeLongis, Kessler, & Schilling, 1989) and health (House, Landis, & Umberson, 1988). Married couples in the United States regard their spouse as their central social partner (Lugaila, 1998), so it is not surprising that marriage impacts mental health and well-being to a greater extent than do other social relationships (Holt-Lunstad, Birmingham, & Jones, 2008; Teo, Choi, & Valenstein, 2013; Whisman, Sheldon, & Goering, 2000). Married adults are healthier and happier than single individuals (see Kiecolt-Glaser & Newton, 2001, for a review), although this association is critically moderated by marital quality, which is predictive of higher life satisfaction, lower depression, and lower blood pressure (Holt-Lunstad et al., 2008). Recent studies examining how marital quality "gets under the skin" have primarily focused on endocrine and cardiovascular pathways to health (e.g., Sbarra, 2009; Whisman & Uebelacker, 2012). In this paper, we probe a mechanism by which marital quality may affect individuals' physical and mental health—by impacting emotional responses to positive and negative events.

Despite its potential for improving well-being, depending on marital quality, marriage can be a source of interpersonal conflict that serves as a chronic social stressor. For example, marital strain can reduce married individuals' reported well-being to levels below those of unmarried adults (Coyne & DeLongis, 1986; Gove, Hughes, & Style, 1983). Compared to the impact of social relations with friends or relatives, dissatisfaction in the marital domain is more strongly associated with the incidence of psychiatric disorders in a large community sample, accounting for variance over and above the effects of other sources of social strain (Whisman et al., 2000). Underscoring the toxic effects of a strained marital relationship, criticism from a spouse (measured objectively or subjectively) robustly predicts subsequent relapse from unipolar depression (Hooley, 2007; Hooley & Teasdale, 1989). In addition, epidemiological studies have found that marital dissatisfaction significantly increases the risk for a major depressive episode when controlling for prior depression history, strongly suggesting that marital strain is etiologically relevant to depression (Teo et al.,

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Dr. Greischar, our longtime collaborator on this project, passed away on 11/20/2011.

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2013; Whisman & Bruce, 1999). Collectively, these studies indicate that marital strain is a powerful stressor with serious costs to emotional well-being.

One mechanism through which marital strain may exert its toll on mental health is by impacting emotional responding and regulatory processes. Emotional responding congruent with a resilient profile is often conceptualized as the ability or propensity to recover from negative emotional provocation with a faster return to baseline, and to prolong positive emotional responses within a healthy range (Davidson, 2000; Thompson, 1994). Marriage provides a source of social and emotional support in the face of negative events, which can serve as a buffer for stress (Kessler & Essex, 1982). In addition, sharing of positive events among married partners is prospectively associated with relationship well-being (Gable, Gonzaga, & Strachman, 2006), suggesting that marriage may also enhance mental health by promoting the cultivating of positive events. Accordingly, sharing positive events with someone is associated with greater positive affect and life satisfaction (Gable, Reis, Impett, & Asher, 2004). In depression, the psychiatric disorder that marital stress has been most frequently associated with, emotion disturbances have been consistently found in the positive-affect dimension: the results from a recent meta-analysis suggest that depressed individuals show robust decreases in responding to positive stimuli (Bylsma, Morris, & Rottenberg, 2008), resonating with prior results showing high specificity of positive affect reductions in depression (Mineka, Watson, & Clark, 1998; Watson, Gamez, & Simms, 2005; Watson & Naragon-Gainey, 2010). Conversely, results speaking to alterations in emotional responding to negative events are less consistent, ranging from slower recovery to negative affect provocation in at-risk populations (Shuls, Green, & Hillis, 1998) to blunted responding to negative information in major depression (Bylsma et al., 2008).

Although most laboratory studies of emotional processing report magnitude of responding at a single time point during or following an emotional stimulus presentation, Davidson (2000) proposes that changes in the time course of emotional responding, in particular following emotional provocation, may constitute a hallmark of resilience. The vast majority of an individual's time in the world does not involve direct confrontation with emotionally provocative stimuli. In fact, a recent report reveals that people spend 47% of their awake time mind wandering (Killingsworth & Gilbert, 2010). Such time spent with self-generated thoughts permits interindividual variability to mold one's dispositional tone. Accordingly, Davidson (2000) postulated that meaningful interindividual heterogeneity in emotional responding would be found not only during, but also after emotional provocation (i.e., the return-to-baseline, or "recovery" period), a time during which participants could theoretically continue to process the evoked emotion to varying degrees, depending on the nature of their self-generated cognitions, as well as the persistence of both central and autonomic response patterns that reflect the emotion cascade. Recent findings from studies of depressed individuals and at-risk populations that disentangled initial reactivity and recovery in emotion-processing paradigms support this proposition. While watching a humorous movie, dysphoric individuals report levels of positive affect comparable to control participants, but they show a steeper decline of this positive affect following movie-clip offset (McMakin, Santiago, & Shirk, 2009). Consistent with the idea that the time course of responding to positive stimuli is altered in depression, a neuroimaging study revealed that, although depressed individuals appear able to upregulate positive affect in the beginning of an experimental session, as evidenced by activation of the nucleus accumbens (a brain region implicated in reward processing), this ability declines over the experimental session, compared to nondepressed individuals (Heller et al., 2009). In summary, findings from studies that have differentiated between initial reactivity and sustained responding to an emotion provocation suggest changes in the maintenance of positive emotional responding may be an important factor underlying vulnerability to psychopathology.

Although the impact of marital quality on the magnitude of responding to emotion-evoking stimuli has not been previously examined in the laboratory, evidence regarding the effects of acute and chronic stress on affective processing is consistent with the hypothesis of stress-induced exacerbation of negative and attenuation of positive affect. For instance, adults selectively allocate attentional resources toward threat-relevant stimuli following an acute stress manipulation (Mogg, Mathews, Bird, & Macgregor-Morris, 1990). In rats, prior exposure to a chronic social stressor, such as the social defeat paradigm, predicts heightened subsequent responding to an acoustic startle (Pulliam, Dawaghreh, Alema-Mensah, & Plotsky, 2010).

Stress also impacts positive emotion processing: In stressful situations such as military training, U.S. cadets report decreased ratings of pleasure in response to positive provocations (Berenbaum & Connelly, 1993). Women under acute stress produced by threat of shock show blunted reward responsiveness (Bogdan & Pizzagalli, 2006; Bogdan, Santesso, Fagerness, Perlis, & Pizzagalli, 2011). In addition, individuals reporting higher levels of stress in the recent past show reduced reward learning (Pizzagalli, Bogdan, Ratner, & Jahn, 2007). Similarly, in rats, social defeat can produce a persistent diminution in the anticipation of (Rygula et al., 2005) and preference for (Von Frijtag et al., 2000) a highly rewarding sucrose solution, considered animal homologues for human anhedonia (Willner, Muscat, & Papp, 1992). Chronic mild stress protocols in rats and mice also produce similar deficits in hedonic responding (for a review, see Willner, 2005). In summary, convergent evidence from studies of acute and chronic stress in humans and animals demonstrate meaningful emotion-processing alterations following stress exposure. Whether long-lasting marital strain may have similar consequences is currently unknown, and examining this question may illuminate an important pathway through which this social stressor could predispose an individual to adverse psychiatric and physical health outcomes (and, conversely, if marital quality is high, could serve as a protective factor for the individual).

Therefore, in the current study of a longitudinal sample of adults, we used an individual-differences approach to identify how the magnitude and time course of responding to both unpleasant and pleasant emotion-evoking stimuli vary as a function of long-lasting marital strain. We adopted a psychophysiological measure with excellent temporal resolution, facial electromyography (EMG) collected over the corrugator supercilii muscle, to assess the time course of responding to pleasant and unpleasant pictures. Corrugator EMG is an objective and well-validated index of affective state (Lang, Greenwald, Bradley, & Hamm, 1993). Specifically, corrugator EMG activity is increased by negative affect, and attenuated by positive affect (Lang et al. 1993; Larsen, Norris, & Cacioppo, 2003; Neta, Norris, & Whalen, 2009; Rymarczyk, Biele, Grabowska, & Majczynski, 2011), where the magnitude of change in corrugator activity in response to a valenced picture presentation correlates highly with self-reported ratings of the picture valence (e.g., Lang et al. 1993). Further, given its high temporal resolution, corrugator EMG can index not only the magnitude of the initial reactivity to, but also the recovery from and/or prolongation of,

emotional provocation (e.g., Javaras et al., 2012). It is thus ideally suited to measure chronometric features of affective responding. Accordingly, corrugator EMG recordings to pictorial stimuli are known to provide a highly reliable estimate of individual differences in emotion regulation (Lee, Shackman, Jackson, & Davidson, 2009). As mentioned above, as affective dysfunction has been characterized by changes in the time course of emotional responding (Davidson, 2000), we examined whether long-lasting marital strain, measured longitudinally, was associated with short-lived responding to positive stimuli and prolonged responding to negative stimuli.

Method

Participants

Participants provided informed consent, and all procedures were approved by the local institutional review boards. Recruitment was done as part of the Midlife in the United States (MIDUS) study, a large longitudinal study of health and well-being (www.midus.wisc.edu). The MIDUS study began in 1995/96 with a national sample of Americans aged 25 to 74, including twins, recruited through a random digit dialing (Brim, Ryff, & Kessler, 2004). Of the original 7,108 MIDUS I participants, 1,914 were twins. Data collection focused on sociodemographic and psychosocial assessments obtained through phone interviews and self-administered questionnaires. In 2004/05, these survey assessments were repeated (MIDUS II). The retention rate from MIDUS I to MIDUS II was 75% (adjusted for mortality). Females, Caucasians, married individuals, those with better self-reported health, and those with more education had the highest retention rates (Radler & Ryff, 2010).

A total of 331 adults (aged 36–84 years, $M_{age} = 55.41$ years, $SD = 11.12$; 183 or 55.2% females) agreed to participate in the laboratory-based emotion study. The data of 116 adults (aged 39–84 years, $M_{age} = 56.82$ years, $SD = 10.37$; 59 or 50.9% males) who were either married or cohabiting with the same partner during MIDUS I and II data collection waves (established by crossing the information on marital status and marriage date across both assessments; $M_{years\ married} = 31.33$; $SD = 12.18$) and had corrugator EMG data recorded were retained for this analysis (25/141 married individuals did not have corrugator EMG data recorded, thus their exclusion yields the $N = 116$ individuals comprising the sample hereby analyzed). One hundred and fourteen (98.2%) of those individuals indicated "married" as their marital status on the first data collection wave, and all of them (100%) indicated "married" as their marital status on the second wave; the two participants whose marital status changed were already cohabitating with their partners during the first assessment and married them in that same year. Participants were comprised of two subsamples of the MIDUS study: a main (55.2%) sample and a twin (44.8%) sample. Among individuals recruited from the twin sample, 14 pairs of twins participated in the study.

Materials

Marital stress assessment. At both baseline (MIDUS I) and longitudinal follow-up (MIDUS II), participants reported their experienced levels of marital stress on a 6-item scale (cf. Block, He, Zaslavsky, Ding, & Ayanian, 2009; Lachman & Agrigoroaei, 2010; Lachman, Rocke, Rosnick, & Ryff, 2008; South & Krueger, 2008). This questionnaire assesses the frequency with which the participant's spouse is a source of demand, criticism, tension/arguments, annoyance, and feelings of being let down, using a 4-point Likert scale (1 = *often*, 2 = *sometimes*, 3 = *rarely*, and 4 = *never*). This scale (adapted from Schuster, Kessler, & Aseltine, 1990) is reliable, as indicated by data collected in the large MIDUS II sample ($N = 3{,}047$), where Cronbach's $\alpha = .87$. Reliability was equivalently high in our sample ($N = 116$), with Cronbach's $\alpha = .85$ at MIDUS I, and Cronbach's $\alpha = .87$ at MIDUS II. Responses to the marital stress questionnaire were reverse coded and averaged such that higher scores reflected higher levels of marital stress.

Depressive symptoms assessment. Depression symptomatology, also measured at MIDUS I and MIDUS II, was assessed based on the Composite International Diagnostic Interview (CIDI). The CIDI is a structured interview designed to be used by trained interviewers who are not clinicians to make diagnoses based on the third edition–revised of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-III-R; American Psychiatric Association, 1987). World Health Organization field trials have documented good reliability (Wittchen et al., 1991) and validity (Farmer, Katz, McGuffin, & Bebbington, 1987; Farmer, Jenkins, Katz, & Ryder, 1991) of the CIDI diagnoses. The CIDI consists of seven items indexing depressive symptoms, including problems in eating, sleeping, energy, concentration, feelings of self-worth, and suicidal thoughts or actions. A diagnosis of major depression requires a period of at least 2 weeks of at least four depressive symptoms most of the day and nearly every day within the last year that the participant was interviewed.

Emotion-responding task. As previously described (van Reekum et al., 2011), participants viewed a total of 90 color images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005), which were selected on the basis of the valence and arousal ratings provided with the IAPS. Thirty negative (valence $M = 2.89$, $SD = 0.61$; arousal $M = 5.35$, $SD = 0.54$) and 30 positive (valence $M = 7.24$, $SD = 0.44$; arousal $M = 5.23$, $SD = 0.73$) pictures matched in arousal, and 30 neutral images (valence $M = 5.14$, $SD = 0.52$; arousal $M = 3.22$, $SD = 0.73$), significantly lower in arousal than negative and positive images, were presented in randomized order. Pictures were also matched for luminance, complexity, and social content.

Procedure

Levels of marital stress were assessed at MIDUS I and MIDUS II via a questionnaire completed at home, on average 9.12 years ($SD = .36$) apart (the exact completion date for the first wave of data collection was missing for two participants). To derive a reliable measure reflecting chronically experienced marital stress, responses to the marital stress scale were averaged across those two time points of data collection. Participants were subsequently invited to come to the laboratory for the assessment of spontaneous emotional responding to positive and negative pictures on average 2.84 ($SD = 1.34$) years following the second assessment of marital stress.[1]

1. Among the 116 participants, 110 (94.8%) were still married during the emotion task. Because our hypothesis concerned the effects of chronic marital stress assessed longitudinally and all participants met criteria for study inclusion (i.e., they were married or cohabiting with the same romantic partner for a minimum of 9 years and reported on levels of marital stress

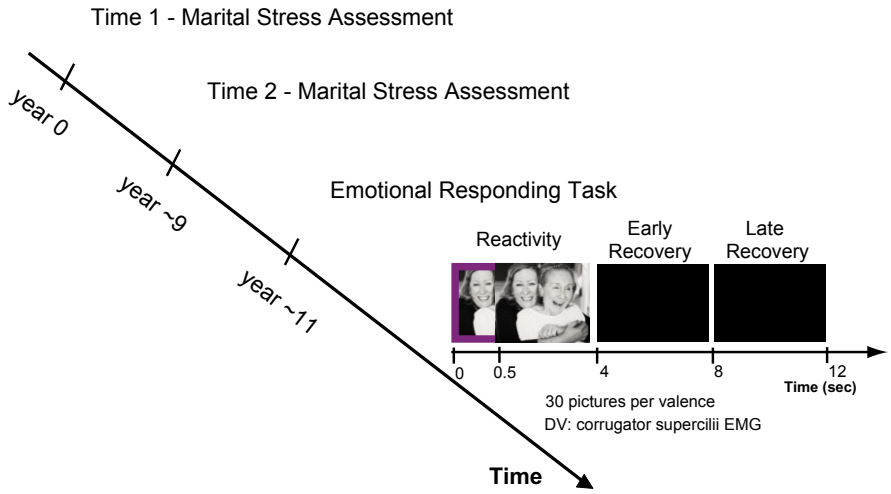

Figure 1. Experimental timeline. Married individuals reported on their experienced levels of marital stress twice on average 9 years apart. Approximately 2 years following the second questionnaire data collection wave, participants came to the laboratory for an assessment of their spontaneous reactivity to and recovery from emotional images. Corrugator EMG activity, a measure sensitive to emotional valence, was recorded continuously throughout the experiment. Representative positive picture retrieved from http://commons.wikimedia.org/wiki/File:Love_and_happiness.jpg (by Ann Gordon, Detroit, MI).

Upon coming to the laboratory and after receiving a detailed explanation of the experiment, participants provided informed consent. Next, they sat on a chair and underwent skin cleaning and preparation for corrugator EMG sensor application (cf. Fridlund & Cacioppo, 1986). Participants were positioned approximately 60 cm from a computer monitor. After a 1-s fixation cross, pictures were presented for 4 s and followed by an intertrial interval that varied randomly between 14–18 s (Figure 1). To ensure continuous alertness and engagement during the task, each picture was surrounded by either a yellow or a purple border during the first 0.5 s of presentation, and participants were instructed to make a button press as quickly as possible to indicate the border color (see van Reekum et al., 2011). Participants were also asked to maintain their gaze on the screen and avoid closing their eyes while the picture was displayed, and to refrain from making body and head movements throughout the task.

Corrugator EMG acquisition. Corrugator data were continuously acquired throughout the task using two 4-mm Ag/AgCl sensors filled with electrogel (Sensormedics Electro-Cap International Inc., Eaton, OH; and Biopac Systems, Inc., CA) placed on top of the left or right eyebrow (counterbalanced across participants) in accordance with published guidelines (Tassinary, Cacioppo, & Geen, 1989). A ground sensor was placed on the center of the participant's forehead. The sensor regions were cleaned using distilled water and 70% isopropyl alcohol (Dynarex Inc., Orangeburg, NY), then slightly abraded using Mavidon Skin Prep (Mavidon Medical Products, Nailsea, UK) prior to sensor placement to reduce skin impedance to an acceptable level (below 20 kΩ). Corrugator EMG data were acquired at 1000 Hz (with a gain of 10000 using SAI Bioelectric Amplifiers, SA Instrumentation Co., Encinitas, CA, for a subset of participants; and with a gain of 5000 using Biopac Systems Inc., CA, for another). Corrugator EMG data were acquired with a high-pass filter at 1 Hz and a low-pass filter at 3 KHz.

experienced with their partner twice), we elected to present the data for the complete sample.

Picture Ratings

A subsample of participants ($N = 86/116$) provided valence and arousal ratings of the pictures after completing the emotion-responding task. They did so by using either the 9-point Likert scale with Lang et al.'s (2005) wording, or a picture grid (where ratings were eventually recoded into 9-point valence ratings similar to the Lang valence and arousal 9-point scales; Larsen et al., 2003; for additional details, see van Reekum et al., 2011). Given the difference in method of the obtained ratings, these data should be interpreted with caution.

Data Processing and Analysis

As previously reported (van Reekum et al., 2011), a fast Fourier transform in 0.5-s Hamming windowed chunks yielded power density values (μV^2/Hz for the 45–200 Hz EMG band) from artifact-free corrugator data. Values were log-transformed to correct for skewness and z-transformed within subjects to control for large individual differences in response magnitudes. Second-by-second corrugator data were baseline corrected by subtracting averaged corrugator power from 1 s preceding the onset of each trial. As illustrated in Figure 1, for each negative, neutral, and positive condition, corrugator EMG power was averaged into three distinct epochs for analysis: the first 4 s of picture presentation (reactivity), the first 1–4 s following picture offset (early recovery), and the subsequent 4-s period after picture offset, 5–8 s postoffset (late recovery). See van Reekum et al. (2011) for the visual depiction of the temporal profile of the corrugator EMG data in a subsample from the MIDUS emotional-processing study ($N = 159$).

To examine whether long-lasting levels of marital stress were associated with later-measured depressive symptoms in this sample (independently of initial depressive symptoms) as previously reported (e.g., Teo et al., 2013; Whisman & Bruce, 1999), a multiple linear regression was conducted entering participants' age, gender, study sample of origin, and Time 1 depressive symptoms as covariates in a model predicting Time 2 depressive symptoms from chronic marital stress.

To address our primary aim and test the effects of chronically experienced levels of marital stress on positive and negative affective responding in the laboratory, a 3 × 3 mixed model multivariate analyses of covariance (MANCOVA, Type III sum of squares) was conducted with valence (negative, neutral, and positive) and epoch (reactivity, early recovery, and late recovery) entered as within-subjects factors, and reported marital stress as a continuous between-subjects variable. Additionally, participants' age, gender, and study sample of origin were entered as between-subjects covariates in the model; all statistical relations shown below hold those covariates constant. The MANCOVA test is appropriate for this mixed design as it is not dependent upon the assumption of sphericity like univariate tests are (O'Brien & Kaiser, 1985). Levels of marital stress and age were zero-meaned to prevent these between-subjects covariates from changing the main effects values in the model (Thomas et al., 2009). The influence of marital stress on affective responding was assessed via its interaction with valence and epoch.

A significant interaction of valence and/or epoch with marital stress (i.e., $p < .05$) indicating an effect of marital stress on corrugator EMG was followed up by tests for each of the epochs to determine which valence and epoch specifically carried the effect. To render emotional recovery independent from levels of responding during the reactivity epoch, we residualized recovery (removing the contribution of reactivity) separately for each valence condition and for each of the recovery epochs. In the event of a significant effect of marital stress on emotion reactivity or recovery, interaction effects with age and gender were explored.

To rule out that a pre-existing depressogenic affective style confounded the relationship that we uncovered between persistent marital stress and corrugator EMG responding to positive pictures, we (a) examined whether depression symptoms at Time 1 were related to marital stress, (b) examined whether the relation between the marital stress and positive-stimulus responding held while statistically controlling for depression symptomatology at Time 1, and (c) tested the reverse causal model by examining whether averaged depressive symptoms over the two time points predicted marital stress (see "Disentangling prior depression from marital stress and short-lived responding to positive pictures" below).

Given the previously demonstrated relationship between depression and short-lived responding to positive stimuli, we examined whether short-lived responses to positive pictures were related to depression symptoms at Time 2. Following a positive result, given that chronic marital stress was associated with both short-lived responding to positive pictures and with increased depressive symptoms at Time 2, we tested whether short-lived responding to positive stimuli worked as a plausible statistical mediator between persistent marital stress and depression symptoms at Time 2 (see "Affective responding as a plausible proximal mechanism underlying the marital stress-depressive symptoms association"). To do so, we tested a mediational model requiring that the plausible mediator (corrugator EMG to positive pictures) predict the outcome variable (Time 2 depression) independently of the initial variable (marital stress; cf. Baron & Kenny, 1986). In addition, we confirmed the plausible mediation effect using a Sobel test (Preacher & Hayes, 2004).

Because we averaged levels of marital stress reported over the 9-year period to capture a long-lasting social stressor, we ran additional analyses to ensure that marital stress at both assessments was associated with short-lived responses to positive pictures, as well as that the association between marital stress and emotional responding was robust among individuals whose levels of marital stress did not fluctuate substantially across the two assessments (see "The stability of marital stress and responses to positive stimuli").

Finally, to confirm that our critical findings held independently of family dependence among the twins present in our sample (i.e., 14 pairs), a generalized estimating equation model (Type III) was run, specifying an exchangeable correlation matrix and accounting for clustering by family membership (see "Controlling for effects of age, gender, and family dependency").

Results

Marital Stress

The mean levels of stress reported in the first ($M = 2.12$, $SD = .51$) and second ($M = 2.13$, $SD = .60$) marital stress assessments were comparable, $t(114) = -.29$, $p > .7$. Both values were comparable to levels of stress found in the larger MIDUS sample, as indicated by MIDUS II assessments, $M = 2.14$ ($SD = .61$), $N = 3{,}047$, ps $> .6$. The correlation between levels of reported stress across the two assessments was strong, $r(114) = .59$. As mentioned previously, to obtain a robust index of long-lasting marital stress and relate it to our assessments of emotional reactivity and recovery, we averaged experienced stress reports across the two time points of data collection. The average level of marital stress experienced by our participants in the 9-year period between assessments was 2.12 ($SD = .49$).

Depression Symptoms

The mean level of depressive symptoms reported in the first assessment was 0.70 ($SD = 1.79$), and in the second assessment, 0.47 ($SD = 1.38$). Despite levels of depression having decreased on average over this 9-year period, this difference did not reach statistical significance, $t(115) = 1.32$, $p > .18$. Sixteen individuals (13.7% of the sample; 9 or 56.3% females) reported symptoms of depression on the first assessment, and 13 (11.2% of the sample; 6 or 46.15% females) did so on the second assessment; all 16 met criteria for major depression at Time 1, and nine (69.2%; 5 or 55.6% females) met criteria for major depression at Time 2. Of the nine who met criteria at Time 2, four were new cases that were not present at Time 1.

Picture Ratings

Analyzing the data from the subsample of our participants for whom we had subjective picture ratings available ($N = 86$), we found that valence ratings of the pictures were significantly modulated by valence, such that positive pictures were rated more positively ($M = 6.96$, $SE = .087$) than neutral ($M = 5.69$, $SE = .085$) ones, which in turn were rated higher in valence than negative pictures ($M = 3.23$, $SE = .087$), all ps $< .001$. In addition, we confirmed that this sample regarded the positive ($M = 2.63$, $SE = .13$) and negative pictures ($M = 2.62$, $SE = .13$) as equivalently arousing, $p > .88$, and rated pictures of both positive and negative valence as significantly more arousing than the neutral pictures ($M = 1.57$, $SE = .11$), ps < 001.[2]

2. Following an anonymous reviewer's suggestion, we examined whether levels of persistent marital stress were associated with participants' subjective appraisal of the pictures, as denoted by their own ratings of valence and arousal. We found that higher marital stress was significantly associated with more negative ratings of neutral pictures, $r = -.228$, $p = .035$. Marital stress was also negatively, albeit nonsignificantly,

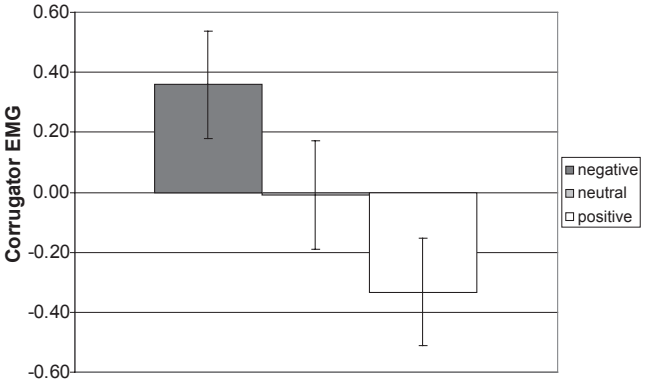

Figure 2. *Z*-scored and baseline-corrected estimated marginal means of corrugator EMG activity to pictures of negative, neutral, and positive valence, averaged across reactivity and recovery epochs, while controlling for age, gender, and sample of origin. Error bars represent 95% CI, computed with the variance pooled across both valence and epoch within-subjects factors (Masson & Loftus, 2003).

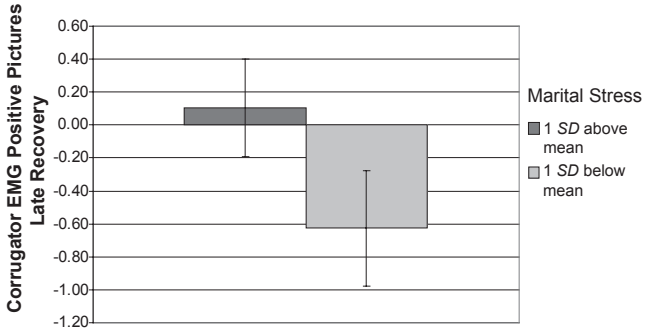

Figure 3. *Z*-scored and baseline-corrected estimated marginal means of corrugator EMG activity to positive pictures during the late recovery epoch, plotted as a function of levels of marital stress (1 *SD* above and below the mean), while controlling for initial reactivity to positive pictures, age, gender, and sample of origin. Error bars represent 95% CI.

Corrugator EMG Modulation by Pictures

Confirming findings previously reported in van Reekum et al. (2011) in this sample, valence strongly modulated corrugator EMG activity, $F(2,109) = 8.94$, $p < .001$, $\eta_p^2 = .14$, such that corrugator EMG activity was potentiated by negative ($M = .359$, $SD = .045$) relative to neutral ($M = -.009$, $SD = .040$) images and, importantly, attenuated to positive ($M = -.333$, $SD = .046$) relative to neutral images, all ps $< .001$ (see Figure 2).

Marital Stress and Affective Responding

The results of the MANCOVA indicated a three-way interaction between levels of experienced marital stress, valence, and epoch, $F(4,107) = 3.50$, $p = .01$, $\eta_p^2 = .11$. Follow-up MANCOVAS for each epoch of emotional responding indicated that only during the late recovery period following the emotion induction did marital stress interact with valence in predicting corrugator modulation, $F(2,109) = 6.24$, $p = .003$, $\eta_p^2 = .10$. Specifically, greater levels of marital stress were associated with decreased attenuation of corrugator EMG to positive pictures during the late recovery epoch, $r(114) = .30$, $p = .001$. The association between marital stress and recovery from negative pictures was not significant, $r(114) = -.14$, $p > .13$. Figure 3 displays how participants with levels of marital stress 1 *SD* above and below the mean differed in their responding to positive images: While participants reporting low marital stress continued to show relative corrugator EMG attenuation to positive images between 5 and 8 s following positive-picture offset, this was not true of participants reporting high marital stress, whose corrugator EMG responses to positive pictures had returned to baseline by that point in time. In summary, individuals who experienced higher marital stress over a 9-year period showed short-lived responses to positive affect provocation.

Further examination of the correlation between levels of marital stress and corrugator responses to positive pictures confirmed that the effect of marital stress pertained to the temporal parameters of positive emotion responding: During the initial reactivity epoch (when positive pictures were still on the screen), marital stress did not modulate corrugator EMG responding, $r(114) = .03$, $p > .7$ (Figure 4). The test of the difference between correlation coefficients revealed that the association between marital stress and positive-picture responding was, indeed, significantly stronger during the late recovery period than during the reactivity period, $t(113) = 2.12$, $p = .036$.

The results for the early recovery period fell between those of reactivity and the later recovery period, such that the relationship between marital stress and corrugator EMG (residualized for initial reactivity) was positive, although not significantly so, $r(114) = .11$, $p = .20$. This correlation was marginally weaker in the early versus late recovery period, $t(113) = -1.92$, $p = .057$, but was not significantly different from the same correlation in the reactivity period, $t(113) = .62$, $p > .5$. Collectively, these data provide evidence that chronic marital stress is associated with short-lived responses following positive-emotion induction, independently of initial levels of positive-emotion reactivity.[3]

Disentangling Prior Depression From Marital Stress and Short-Lived Responding to Positive Pictures

It is possible that individuals' initial depressive symptoms could have contributed to both a depressogenic affective style (characterized by short-lived responding to positive pictures), as well as higher reports of marital stress. Thus, we conducted the following general linear model (GLM) analyses to address this issue. First, we found that marital stress was not significantly associated with

associated with valence ratings of both positive pictures, $r = -.09$, $p = .39$, and negative pictures, $r = -.10$, $p = .339$. Marital stress was not associated with arousal ratings, ps $> .34$.

3. Following an anonymous reviewer's suggestion, we examined whether marital empathy/support contributed to longer-lived responding to positive pictures. MIDUS included a measure of marital support using a 6-item scale, which included items such as "How much does your spouse or partner really care about you?"; "How much do you rely on him or her for help if you have a serious problem?"; and "How much does he or she understand the way you feel about things?" We examined whether prolonged marital support (i.e., responses averaged across the two time points of data collection, as performed with the spousal strain measure) predicted prolonged responding to positive pictures (controlling for age, sample of origin, gender, and initial reactivity to the positive pictures). We found that marital empathy/support did not predict prolonged responding to the positive pictures, $t(110) = -1.2$, $p = .21$, suggesting that negative aspects of marriage may be more strongly related to poorer regulation of positive affect.

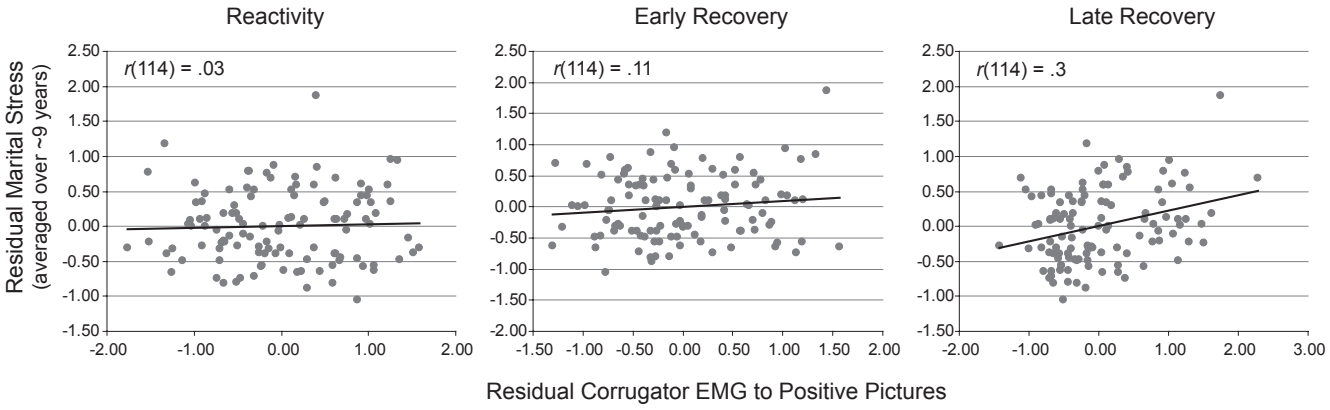

Figure 4. The relationship between levels of marital stress (averaged over 9 years) and responding to positive pictures as indexed by corrugator EMG activity during initial reactivity, early, and late recovery epochs. The residuals of both measures are plotted, after controlling for age, gender, and sample of origin (as well as for initial positive-picture reactivity in the recovery estimates). Note that the relationship at late recovery epoch remains significant without the outlier, $r(113) = .25$, $p = .007$.

symptoms of depression at Time 1, B = .46, $t(111) = 1.74$, $p > .15$, suggesting that a depressogenic affective style did not significantly predispose individuals to higher levels of marital stress over time. In contrast, marital stress was significantly associated with depressive symptoms at Time 2, while controlling for depression symptoms at Time 1 (as well as all the covariates), B = .56, $t(110) = 2.38$, $p = .019$, suggesting that marital stress may be etiologically relevant to depression (e.g., Teo et al., 2013; Whisman & Bruce, 1999).

Additionally, we found that prolonged marital stress continued to predict short-lived responding to positive pictures even after controlling for depression scores at Times 1 and 2, B = .46, $t(108) = 2.68$, $p = .008$. Of interest, depression symptoms at Time 2 predicted short-lived responding to positive pictures, B = .165, $t(109) = 3.52$, $p = .002$, (the relation remained significant if additionally controlling for marital stress, B = .135, $t(108) = 2.68$, $p = .008$), reinforcing the idea that reduced maintenance of responding to positive events is a hallmark of a depressogenic affective style (Heller et al., 2009; McMakin et al., 2009).

To rule out the reverse causal model (i.e., does persistent depression predict marital stress?), we entered averaged symptoms of depression experienced over the 9-year period in a regression model as a predictor of marital stress at Time 2, controlling for marital stress at Time 1, gender, age, and sample of origin. We found that averaged depressive symptoms were unrelated to marital stress at Time 2, B = .01, $t(110) = .22$, $p > .79$. We also found that short-lived corrugator EMG attenuation to positive affect did not predict marital stress at Time 2 while controlling for persistent depression, marital stress at Time 1, and the demographic variables delineated above, B = .036, $t(109) = .56$, $p > .6$. Thus, in this sample, persistent marital stress predicted both a depressogenic affective style characterized by short-lived corrugator EMG attenuation following positive-picture processing, as well as depression symptoms longitudinally, but no support was evident for the reverse directional pattern.

Affective Responding as a Plausible Proximal Mechanism Underlying the Marital Stress-Depressive Symptoms Association

Given chronic marital stress was associated with short-lived responding to positive pictures as indexed by corrugator EMG, as well as with increased depressive symptoms at Time 2, we examined affective responding as a plausible mediator between marital stress and depression. Such models require demonstrating that the plausible mediator (corrugator EMG responding) predicts the outcome variable (Time 2 depression) independently of the initial variable (marital stress; cf. Baron & Kenny, 1986). Hence, we entered levels of marital stress in a simultaneous linear regression model, together with the demographic covariates delineated above, and found that short-lived corrugator EMG responding to positive pictures in the late recovery epoch continued to predict Time 2 depression after controlling for levels of marital stress, B = .46, $t(108) = 2.68$, $p = .008$. Critically, including the recovery of corrugator EMG responding to positive pictures in the regression model shifted the relationship between marital stress and depression symptoms to statistical nonsignificance, B = .35, $t(108) = 1.47$, $p = .17$, thereby providing evidence for a plausible mediation effect. The result of a Sobel test (Preacher & Hayes, 2004) confirmed that short-lived corrugator EMG responses to positive pictures significantly mediated the relationship between marital stress and depressive symptoms at Time 2, $Z = 2.08$, $p = .036$, when controlling for Time 1 depression symptoms, initial reactivity to positive pictures, age, gender, and sample of origin.

The Stability of Marital Stress and Responses to Positive Stimuli

We averaged levels of marital stress reported twice over the 9-year period to capture a long-lasting social stressor, which we expected to exert detrimental effects on mental health. Nevertheless, it is important to establish that (a) marital stress at both assessments was associated with short-lived responses to positive pictures, and (b) the marital stress → short-lived responding to positive stimuli association was robust among individuals whose levels of marital stress did not fluctuate substantially across the two assessments. Thus, while controlling for age, gender, and sample of origin (in addition to initial responding to positive pictures), we ran the following analyses to address these issues: First, we confirmed that short-lived responding to positive pictures was significantly predicted by marital stress assessed at Time 1, $r(114) = .32$, $p < .001$, as well as at Time 2, $r(114) = .23$, $p = .01$. Second, because the relationship between marital stress and responding to positive images should be particularly robust for participants who

experienced equivalent levels of marital stress across the two assessments over the 9-year period, we analyzed the data of a subsample of individuals whose levels of marital stress fell consistently in the top ($N = 32$) or in the bottom ($N = 25$) tertiles across the two time points of data collection. This analysis corroborated our prior results, revealing that individuals who were persistently in the bottom tertile for marital stress had longer-lasting responses to positive pictures as indicated by greater corrugator attenuation to positive images at the "late recovery" time point ($M = -.77$, $SE = .13$), relative to individuals who were persistently in the top tertile for marital stress ($M = -.06$, $SE = .11$), $F(1,51) = 16.15$, $p < .001$, $\eta_p^2 = .24$. Thus, when analyzing the data using persistent standing on tertiles of marital stress across the two data collection time points ($N = 32$ top tertile and $N = 25$ bottom tertile) rather than the continuous averaged marital stress variable, we replicated all major results reported here, including the significant interaction between valence, epoch, and marital stress, driven by prolonged corrugator deactivation to positive pictures in the low marital stress tertile group, compared to the high marital stress group.

Controlling for Effects of Age, Gender, and Family Dependency

Neither age nor gender interacted with the effects of marital stress on the modulation of corrugator activity to positive pictures during the late recovery epoch, ps > .15. Finally, to confirm that our critical findings held independently of family dependence among the twins present in our sample (i.e., 14 pairs), a generalized estimating equation model (Type III) was run, specifying an exchangeable correlation matrix and accounting for clustering by family membership. Levels of marital stress continued to modulate responding to positive pictures during the late recovery epoch after accounting for clustering by family membership, B = .43, Wald $\chi^2 = 13.74$, $p < .001$. In sum, the findings we report do not depend on age, gender, or the relatedness of the respondents (siblings and twin status) in this sample.

Discussion

We examined individuals who had been married for a minimum of 9 years to evaluate the association between prolonged marital stress and the initial magnitude, as well as the time course, of emotional responses to positive and negative events in the laboratory. First, we replicated previous findings of robust modulation of corrugator EMG activity by both negative and positive valences, with activation to negative, and deactivation to positive pictures (Lang et al., 1993; Larsen et al., 2003; Neta et al., 2009; Rymarczyk et al., 2011). Next, we demonstrated that persistent marital strain, a potent social stressor, was associated with short-lived response to pleasant pictures as indexed objectively in the laboratory via corrugator EMG recordings (in an association that was independent from individuals' initial depression symptomatology). In addition, we found that decreased maintenance of positive affect worked as a statistical mediator of the relationship between marital strain and depression symptoms. Thus, our study highlights a close interplay between psychosocial stress and emotional functioning, and suggests an affective-processing mechanism through which marital stress may impact mental and physical health. These findings held independently of participants' age and gender in a longitudinal sample of adults.

The finding that a social stressor such as marital strain is associated with alterations in responding to positive stimuli is consistent with research in humans testing the attenuating effects of stress on reward responsiveness (Bogdan & Pizzagalli, 2006; Pizzagalli et al., 2007) and with hedonic deficits previously observed in animal studies of chronic social stress (Rygula et al., 2005; Von Frijtag et al., 2000; Willner et al., 1992). In our study, the relationship between marital stress and positive affect manifested particularly strongly 5–8 s after picture offset: It held independently of initial levels of reactivity to positive pictures and was significantly stronger following, rather than during initial reactivity to, the viewing of pleasant slides. In other words, the effects of marital stress on one's engagement with positive stimuli specifically pertained to the time course of affective responding (Davidson, 2000). Therefore, our study extends the recent literature on the effects of stress on positive affective responding by showing that prolonged marital stress is associated with a failure to maintain picture-elicited attenuation of corrugator EMG indicative of positive affect over time. In addition, our results raise the possibility that a long-lasting psychosocial factor (i.e., persistent marital stress) could increase vulnerability to psychopathology such as depression by altering an individual's propensity to sustain positive affect.

Alternatively, in light of recent evidence highlighting the contribution of sharing positive events with others to one's positive mood and well-being (Gable et al., 2004), it is possible that individuals with lower levels of marital stress may have been cultivating positive events to a greater extent than individuals in strained relationships, thus potentiating the ability to savor positive events. We did not find evidence that marital support, as measured in our sample, was associated with responding to positive pictures. Perhaps a measure more sensitive to the sharing of positive events within a couple (such as experience sampling or behavioral observations) would reveal such findings. Future research measuring both positive and negative aspects of marital quality in relation to health and well-being is needed to disentangle these possibilities.

The reduced maintenance of positive affect observed in individuals reporting higher marital stress explained the relationship between marital stress and depressive symptoms. Marital stress and depressive symptoms have been linked extensively in the past, using diverse methods and samples ranging from retrospective reports of individuals with depression to prospective studies of depression-free newlyweds and adults from large population studies (Beach & O'Leary, 1993; Paykel et al., 1969; Whisman & Bruce, 1999). Here, we replicated this association in an age-diverse longitudinal sample of males and females, and showed that reduction in positive affect maintenance worked as a plausible proximal mechanism underlying the relationship between marital stress and depressive symptoms.

The precise neurobiological mechanisms through which prolonged exposure to a stressful social environment may alter affective responding to positive stimuli in humans remain to be determined. Nevertheless, several studies point to basal gangliar involvement in the reduced hedonic capacity: Caudate volume is negatively correlated with anhedonic symptoms in both depressed and nondepressed samples (Harvey, Pruessner, Czechowska, & Lepage, 2007; Pizzagalli et al., 2009). In addition, decreased engagement of the caudate and nucleus accumbens during the processing of rewards in a reward-learning task has been reported in individuals with depression (Pizzagalli et al., 2009). Relatedly, we have shown that individuals with major depression fail to maintain striatal engagement and prefrontal-striatal connectivity over the time course of a session during voluntary upregulation of positive affect (Heller et al., 2009). Future neuroimaging work on individuals experiencing chronic marital strain would reveal whether

reduced basal gangliar circuitry engagement during processing of appetitive stimuli may be a sequelae of this type of social stressor.

The correlational nature of this study does not allow us to rule out an alternative interpretation of our results; namely, that a pre-existing depressogenic affective style, characterized by reduced maintenance of positive affect, may have contributed to participants' perceiving and/or reporting greater levels of stress in their marital relationship. Indeed, recent evidence points to an overlap in the heritability of hedonic behavior and stress perception (Bogdan & Pizzagalli, 2009). In an extensive review, Barnett and Gotlib (1988) concluded that studies controlling for current depression status provide support for marital adjustment working both as a consequence of as well as an antecedent factor for depression. We opted for the latter well-documented (e.g., Teo et al., 2013; Whisman & Bruce, 1999) etiological perspective between marital stress and an emotion-responding facet relevant to psychopathology primarily because it was consistent with the chronological order in which our data were collected. In addition, our implied causal formulation was strengthened by features of the longitudinal design that allowed us to control for baseline depressive symptoms, as well as to assess marital stress as a chronic, persistent problem for some. Marital strain was unrelated to baseline depression symptoms, and the relationship between persistent marital strain and later depression held independently of baseline profiles. Moreover, when considering a reversal in the causal scenario, we found no support for persistent depression predicting later marital strain. Nevertheless, we underscore the utility of considering bidirectional relations between marital stress and positive-affect reductions in future inquiries.

Marital stress was related to the response to positive images, but not negative images in our study. The valence specificity of the impact of stress on affective functioning was not predicted; hence, it needs to be replicated in future studies. Nonetheless, given the documented role of marital stress on the etiology of depression, it is interesting to note that decreases in positive emotional responses (such as we found) have been suggested to be highly specific to depression, and are more consistently reported in the literature than alterations in the negative emotional responding domain (for a meta-analysis, see Bylsma et al., 2008).

Limitations of the current study warrant further research: First, we assessed individual differences in emotional responding only once, approximately 2 years following the MIDUS II assessment of marital stress. The fact that our investigation uncovered relations between positive-stimulus responding and marital stress despite the 2-year interval between assessments highlights their strength of association. However, it is possible that such associations would have been stronger, or would have extended to negative-stimulus responding as well, had the assessments been conducted closer in time. Second, we did not assess participants' symptoms of depression concurrently with our emotion-processing task. In light of prior work highlighting the specificity of positive-affect processing deficits to depression (e.g., Bylsma et al., 2008; McMakin et al., 2009) and suggesting an etiological role for marital stress and depressive episode onset (e.g., Teo et al., 2013), future work should conduct repeated and longitudinal assessments of marital stress, depression, reactivity to, and recovery from positive and negative emotion provocation using a battery of multimodal behavioral and biological methods. Finally, findings from this study are not generalizable to individuals less prone to staying married. Nonetheless, as highlighted by marital quality researchers, the absence of such individuals in this inquiry may have led to an underestimation of the strength of associations between marital quality, emotional responding, and mental health (Umberson, Williams, Powers, Liu, & Needham, 2006).

In conclusion, in a unique blend of national longitudinal survey research with laboratory-based assessments of affective responding, we found that prolonged marital stress was associated with short-lived responses to positive stimuli, which in turn functioned as a plausible proximal mechanism underlying its association with depressive symptomatology.

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