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Physiological blunting during pregnancy extends to induced relaxation

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Abstract

There is accumulating evidence that pregnancy is accompanied by hyporesponsivity to physical, cognitive, and psychological challenges. This study evaluates whether observed autonomic blunting extends to conditions designed to decrease arousal. Physiological and psychological responsivity to an 18-minute guided imagery relaxation protocol in healthy pregnant women during the 32nd week of gestation ($n = 54$) and non-pregnant women ($n = 28$) was measured. Data collection included heart period (HP), respiratory sinus arrhythmia (RSA), tonic and phasic measures of skin conductance (SCL and NS-SCR), respiratory period (RP), and self-reported psychological relaxation. As expected, responses to the manipulation included increased HP, RSA, and RP and decreased SCL and NS-SCR, followed by post-manipulation recovery. However, responsivity was attenuated for all physiological measures except RP in pregnant women, despite no difference in self-reported psychological relaxation. Findings support non-specific blunting of physiological responsivity during pregnancy.

Keywords

Pregnancy; Relaxation; Autonomic Nervous System; Heart Rate; Respiratory sinus arrhythmia

Pregnancy is associated with dramatic physiological changes in virtually every major organ system. Cardiovascular adjustments alone include increased blood volume, heart rate, and cardiac output, decreased systemic vascular resistance, and decreased arterial pressure (Fu & Levine, 2009; Monga, 1999). Indicators of autonomic balance derived from measures of heart rate variability in both frequency and time domains change over the course of pregnancy. For example, a lower sympathetic to parasympathetic ratio, which reflects greater vagal input, has been reported in early pregnancy followed by reduced vagal activity coupled with enhanced sympathetic activation later in pregnancy (DiPietro, Costigan, &

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Gurewitsch, 2005; Ekholm & Erkkola, 1996; Kuo, Chen, Yang, Lo, & Tsai, 2000; Voss et al., 2000). Pregnancy is also accompanied by fundamental changes to other physiological systems, including the hypothalamic-pituitary-adrenal axis (HPA). In pregnancy, the well-known negative feedback loop between glucocorticoids and hypothalamic control of corticotrophin-releasing hormone (CRH) is modified by the positive feedback loop between glucocorticoids and placental CRH (Robinson, Emanuel, Frim, & Majzoub, 1988). This unique alteration to normal physiology is accompanied by a substantial increase in cortisol as gestation advances (Mastorakos & Ilias, 2003).

A number of studies have reported that, in addition to the dynamic changes in the physiological milieu, pregnancy is associated with blunting of responsiveness to physical and psychological challenges. A fairly extensive body of research has relied on well known cardiovascular reflex maneuvers, such as attempted forced exhalation against a closed airway (i.e., Valsalva maneuver), changes in posture, and isometric exercise (e.g., hand grip). This literature has documented diminished heart rate, heart rate variability, and catecholamine responses to these challenges during pregnancy (Barron, Mujais, Zinaman, Bravo, & Lindheimer, 1986; Ekholm, Piha, Antila, & Erkkola, 1993; Matthews & Rodin, 1992). Pregnancy is further associated with a blunted renin response to thermal stress (Vaha-Eskeli, Erkkola, Schenin, & Seppanen, 1992) coupled with attenuated pain perception (Saisto, Kaaja, Ylikorkala, & Halmesmaki, 2001) and failure to mount a cortisol response (Kammerer, Adams, vonCastelberg, & Glover, 2002) to cold pressor tests.

In contrast to the extensive literature on physical challenges, few studies evaluate the effects of pregnancy on modulating responses to cognitive or psychological challenges using direct comparisons to non-pregnant samples. In one such study, pregnant women displayed reduced diastolic responsivity to mental arithmetic and mirror image tracing tasks, but not differential heart rate responsiveness, at 21 to 23 weeks gestation (Matthews & Rodin, 1992). In contrast, pregnant women showed significantly blunted heart rate and electrodermal (i.e., sympathetic) reactivity and recovery responses to administration of the Stroop Color Word test at both 24 and 36 weeks gestation (DiPietro et al., 2005). A more recent study did not find significant differences in the responsiveness of non-pregnant and pregnant participants (at either 13 to 18 weeks or 26 to 31 weeks gestation) to the Trier Social Stress Test (TSST) in either heart rate or variability (Klinkenberg et al., 2009). Analysis of neuroendocrine responses of participants in the same study revealed attenuated salivary α -amylase responses, a primarily sympathetic derivative, to the TSST in pregnant women at both gestational periods. There was no difference in cortisol reactivity between pregnant and non-pregnant participants, although there was diminished (i.e., prolonged) cortisol recovery to the experimentally induced surge in pregnant women at the earlier gestational age (Nierop, Klinkenberg, Nater, Zimmermann, & Ehlert, 2006).

In summary, there is compelling evidence that pregnancy is associated with blunted responsivity to autonomic maneuvers that manipulate the cardiovascular system, and to a lesser extent, pain perception related to thermal challenges. Parallel data are generally supportive but less extensive regarding cognitive or psychological laboratory challenges. Evidence for attenuation of responsivity to laboratory challenges as pregnancy progresses in studies that include only pregnant women (e.g., DiPietro et al., 2005; Entringer et al., 2010; Glynn, Schetter, Wadhwa, & Sandman, 2004; Nierop et al., 2006) also provides support for this concept. Together, this research is typically interpreted as supporting the position that the physiological milieu of pregnancy confers stress-buffering effects on the developing fetus, and as such, is protective against potentially deleterious effects of maternal stress (deWeerth & Buitelaar, 2005; Glynn, 2010a). Similar hypotheses have been offered to reconcile observed reductions in fearful behavior in other species (e.g., Vierin & Bouissou, 2001).

However, it is equally possible that these observations reveal an overall dampening of maternal physiological lability to *all* experiences, both positive and negative, thereby promoting a condition of measured physiological homeostasis for the fetus. To the extent that pregnancy is characterized by a dampening of autonomic responsivity in general, one might expect attenuation of autonomic responses to laboratory-based cognitive or psychological challenges designed to increase physiological arousal (i.e., Stroop Color Word test or the TSST), *and* to manipulations designed to decrease arousal (i.e., progressive relaxation) since both result in changes to the intrauterine milieu. If, however, physiological blunting is observed in response to manipulations that heighten arousal due to their potential downstream effects on the fetus such as decreased blood flow, it is possible that pregnant women might show an enhanced response to conditions that facilitate the types of maternal physiological alterations that may be of benefit to the fetus. Relaxation techniques may fall into this category.

The relaxation response is generally regarded as the antithesis of the stress response (Jacobs, 2001). Relaxation techniques including guided imagery, meditation, and yoga have been found to reduce psychological distress while decreasing sympathetic and increasing parasympathetic activity in non-pregnant populations (Tang et al., 2009; Vempati & Telles, 2002). Several manipulations designed to induce relaxation in laboratory settings have been shown to be effective at garnering expected cardiovascular system changes in pregnant women including reductions in heart rate and/or blood pressure (Teixeira, Martin, Prendiville, & Glover, 2005; Urech et al., 2010), alterations to both low and high frequency bands within heart rate variability (Satyapriya, Nagendra, Nagarathna, & Padmalatha, 2009), and reducing resistance in the umbilical artery (DiPietro, Costigan, Nelson, Gurewitsch, & Laudenslager, 2008). Reductions in cortisol, ACTH, norepinephrine, and noradrenaline have also been observed, although it is more difficult to ascribe these to the relaxation manipulation itself as opposed to simple rest (DiPietro et al., 2008; Teixeira et al., 2005; Urech et al., 2010).

To our knowledge, no study has compared the relaxation response in pregnant and non-pregnant women. Doing so has practical implications for both the design of relaxation interventions for pregnant women as well as an explicit evaluation of the stress buffering hypothesis. This study assessed responsivity to a guided imagery relaxation protocol in healthy nulliparous women and non-pregnant women of similar age. The measures selected for study include heart rate, the most commonly-used cardiovascular indicator in prior studies. As heart rate is governed by multiple autonomic influences and non-neural factors, it is fairly non-specific; for this reason, we also included respiratory sinus arrhythmia (RSA), a well-known indicator of parasympathetic activation that corresponds primarily to vagal input to the heart (Berntson, Cacioppo, & Quigley, 1993). In addition, electrodermal activity data were collected, measured as changes in skin conductance (SC) mediated by eccrine glands which are uniquely innervated by sympathetic processes (Venables, 1991). Intervals between breaths were quantified to provide both peak to trough fluctuations for RSA quantification and to ascertain maternal compliance to the relaxation task demands. We anticipated that both pregnant and non-pregnant women would display a relaxation response consistent with enhanced parasympathetic (i.e., RSA) and reduced sympathetic activity (i.e., SC) but that the relaxation response of pregnant women would be attenuated.

Method

Participants

Pregnant participants ($n = 54$) were comprised of the nulliparous women for whom adequate autonomic data had been collected out of a larger sample of 100 self-referred pregnant women described elsewhere (DiPietro et al., 2008). Eligibility was restricted to

normotensive, non-smoking women with uncomplicated pregnancies at the time of enrollment carrying singleton fetuses. The comparison group consisted of 28 non-pregnant, healthy women volunteers with no previous pregnancies and who were non-smokers. Pregnant and non-pregnant participants did not differ from one another in terms of age (M age = 29.8 versus 28.6; $t(80) = 1.29$, ns) or education (M years education = 16.8 versus 17.5; $t(80) = -1.49$, ns). Most women in the pregnant and non-pregnant groups were non-Hispanic white (81.5% and 64.3% respectively); the remaining participants were African-American (11.1% and 7.2%) and of Asian or Indian descent (7.4% and 28.5%). The study was approved by the university's Institutional Review Board and all women provided written informed consent prior to participating.

Note that the pregnant group in this study comprises a subsample (nulliparous only) of a larger study and a prior report focused on the effects of maternal relaxation on the neurobehavioral functioning of the fetus (DiPietro et al., 2008). That report presented maternal relaxation data for the entire group (nulliparous and multiparous) but was focused principally on affirming that the manipulation was effective in generating a maternal physiological response in order to evaluate whether there was a resultant fetal response.

Design and procedure

Data were collected at a standardized time in early afternoon (13:30). Pregnant participants were recorded during the 32nd week of gestation, as determined by first trimester ultrasound and clinical confirmation. Non-pregnant women were tested in the follicular stage of their menstrual cycle, consistent with procedures by others (e.g., (Nierop et al., 2006), to partially control for stability in estrogen and progesterone levels. Women were instrumented and 18 minutes of baseline, undisturbed data were collected, followed by an 18-minute guided imagery, progressive relaxation audio recording ("Beach Summer Day," Suki Productions, Cincinnati, OH) delivered through headphones with lights dimmed. Instructions guided women through imagery designed to release tension and foster a relaxed state. Women were monitored in reclined position on a hospital bed with head elevation; pregnant women were shifted slightly to their sides to avoid compression of the vena cava. After the relaxation interval, the lights were switched on, and women evaluated the experience. An additional 18-min post-relaxation recovery period followed during which time women rested silently.

Physiological measures—Continuous physiological signals were amplified using a multi-channel, electrically isolated, bioamplifier (Model JAD-04; James Long Company, Caroga Lake, NY). Data were digitized on a personal computer at 1000 Hz via an external analog to digital board using Snapstream data acquisition system (HEM Data Corporation, Southfield, MI). Electrocardiogram was recorded from three carbon fiber disposable electrodes in triangulated placement (right mid sub-clavicle, left mid-axillary thorax, and upper left thigh for ground lead). Electrodermal activity was monitored from two silver-silver chloride electrodes with a gelled skin contact area placed on the distal phalanges of the index and second fingers of the non-dominant hand. Electrodes were affixed with adhesive collars to limit gel contact to a 1 cm diameter circle and secured with Velcro. Respiration was measured from a bellows apparatus stretched across the ribcage below the breasts.

Data quantification proceeded off-line using the PHY General Physiology System and IBI Analysis Systems (James Long Company). ECG data underwent R-wave detection, manual editing for artifact, and interbeat interval or heart period (HP) computation in ms. Tonic skin conductance level (SCL) was measured by administering a constant 0.5 V root-mean-square 30 Hz AC excitation signal and detecting the current flow. SCL was scaled from 0 to 25 μ S. Phasic skin conductance responses which reflect small, spontaneous fluctuations of skin

conductance around level were also measured by applying a high-pass filter to the raw SCL signal and amplifying the resultant values (i.e., $\pm 2.5 \mu\text{S}$ full scale). These skin conductance responses are labeled as “non-specific” (NS-SCR) to avoid interpreting them as temporally-based responses to stimulus presentations. Respirations were measured by quantifying inspiration to inspiration and expiration to expiration periods based on the detected peaks and troughs of the respiratory waveform. Respiratory period (RP), or the interval between breaths, was computed (s). These data were also used to quantify respiratory sinus arrhythmia (RSA); units represent peak to valley changes in IBI from inspiration to expiration (ms) (Grossman, van-Beek, & Wientjes, 1990).

Data were epoched in 1 minute intervals. Mean values during each 18-minute segment (baseline, relaxation, and post-relaxation) were computed.

Psychological measures—Women completed the Psychological Tension and Physical Assessment subscales of the Relaxation Inventory (Crist, Rickard, Prentice-Dunn, & Barker, 1989), designed specifically to assess the efficacy of relaxation protocols, upon arrival and following the relaxation period. These two of the three subscales of the 45-item inventory include 35 items (e.g., my jaw is set tight; I have a clear mind) rated on 7-point Likert scales. As reported by the authors, test-retest reliability for the Physiological Tension subscale is .87 over 3 days, .95 within day trials, and an alpha coefficient of .89. Comparable values for the Physical Assessment subscale are .87 (days), .97 (trials) and .95 (alpha). After reverse scoring of some items, higher scores reflect greater relaxation.

The Profile of Mood States scale (POMS; McNair, Lorr, & Droppleman, 1971) was administered in its shortened form (Shacham, 1983) to assess psychological state at outset in the event this needed to be included as a control variable. The POMS is a self-report measure of transient mood states that includes six subscales: Anxiety, Depression, Anger, Fatigue, Vigor, and Confusion. Respondents are asked to rate the extent to which they are experiencing a series of mood-related adjectives on 5-point scales ranging from “not at all” to “extremely.” A total POMS score was derived by summing all scales, exclusive of Vigor. The shortened format, in which the original 65 items were reduced to 37, has demonstrated high correlations with the original scale, as well as strong face validity, internal consistency, and convergent and discriminant validity (Baker, Denniston, Zabora, Polland, & Dudley, 2002; Shacham, 1983).

Data analysis

Data were examined to assess distributions and potential outliers. Repeated measures (2×3) analysis of variance (RM ANOVA) stratified by group (pregnant versus non-pregnant) over three time points (baseline, relaxation, recovery) were conducted for heart period (HP), respiratory sinus arrhythmia (RSA), skin conductance (SCL), skin conductance response (NS-SCR) and respiratory period (RP). Psychological efficacy of the manipulation was evaluated with 2×2 RM ANOVA since the Relaxation Inventory was administered only twice. Group $\times$ Time interaction terms were used to determine whether pregnant and non-pregnant women were differentially responsive. Because the relaxation intervention is targeted at the manipulation of breathing, and alterations in RP can have independent effects on RSA (Allen, Chambers & Towers, 2007), RP values at each period were entered as covariates in a second analysis of RSA effects.

Additional post hoc analyses were used to determine whether pregnant and non-pregnant women differed in baseline values, responsivity (baseline to relaxation) and/or recovery (relaxation to post-intervention). *T*-tests were used to compare pregnant and non-pregnant women on baseline POMS sub-scales. Analyses were conducted using SPSS, PASW Statistics 18 (Release 18.0.0).

Results

Missing data resulting from inadequate signal or other technical difficulties in recording during one or more of the three segments occurred as follows: pregnant group, RSA and RP, a total of 4 cases (2 missing relaxation segment; 2 recovery); and non-pregnant group, RSA and RP (two cases, both for baseline and recovery). RSA values for each segment were identified as outliers for one non-pregnant participant and excluded from analyses. As a result, degrees of freedom vary slightly across analyses.

Although pregnant and non-pregnant groups were similar for sociodemographic measures (i.e., age, education level), there was a significant difference in race and ethnicity, such that the non-pregnant sample contained a lesser proportion of non-Hispanic white individuals ($X^2(2) = 6.66, p < .05$). Preliminary repeated measure analysis of variance was conducted by race/ethnicity (White, African-American, and Asian) for each dependent measure; F values were non-significant and less than 1.00 for HP, RSA, and RP. Race/ethnicity differences were apparent, but different, in each of the skin conductance measures (details below). As result, race/ethnicity was examined as a potential covariate in those analyses.

Physiological measures

Main effects for Time—The relaxation manipulation generated significant changes in all physiological measures, with the exception of NS-SCR. Table 1 summarizes the RM ANOVA results including main effects for Group, Time, and Group $\times$ Time interactions. Data are presented in Figures 1a to 1e. Each physiological indicator showed evidence for a relaxation response as noted by the main effect for Time (all $ps < .001$) in the expected direction. That is, HP increased (i.e., heart rate decreased), SCL decreased, RP increased (i.e., breathing slowed), and RSA increased. In general, values returned to near baseline levels when the manipulation was over. The analysis of covariance revealed significant associations between RSA and RP across the recording ($F(1,72) = 4.45, p < .05$).

Main effects for Group—With the exception of NS-SCR, there were large main effects by group status, indicating significant differences on each measure over time in pregnant and non-pregnant participants. As compared to non-pregnant women, pregnant women showed significantly faster heart rate and breathing, and significantly lower SCL. RSA was also decreased in pregnant women, both before and after controlling for RP. Individual contrasts revealed significant differences on each of these measures at baseline ($ps < .001$ for HP, RP and RSA; $p < .01$ for SCL). In contrast, NS-SCR displayed a significant difference in variance at baseline ($p < .001$), but not in mean.

Group by Time interactions—Evidence for differential responsivity as a function of pregnancy status was found for HP and RSA as detected by significant Group $\times$ Time interactions. Control for the group difference in RP in the RSA analyses increased the magnitude and significance level of the interaction. There was also a significant Group $\times$ Time interaction for NS-SCR, but examination of Figure 1c reveals a different pattern of results as compared to other variables. Instead of a similar, but attenuated response by pregnant women, there appears to be no response; this is confirmed by a post hoc contrast ($F(2,106) = 1.45, ns$). In addition, as at baseline, the non-pregnant group has significantly greater variance at both the relaxation and recovery time points ($ps < .001$).

Post-hoc analysis between Times 1 and 2 (responsivity) and Times 2 and 3 (recovery) indicated that non-pregnant women were significantly more responsive ($F(1,80) = 25.47, p < .001$) and showed greater recovery ($F(1,80) = 4.31, p < .05$) in HP than pregnant women. Also, non-pregnant women showed marginally greater RSA responsivity ($F(1,75) = 3.67, p = .059$) and significantly greater recovery ($F(1,73) = 7.48, p < .01$); these differences were

magnified when RP was controlled ($F(1,74) = 9.44, p < .01$ and $F(1,72) = 9.36, p < .01$, respectively).

With respect to skin conductance measures, there was a tendency for non-pregnant women to show marginally greater responsivity and recovery in SCL ($F(1, 80) = 3.67, p = .059$ and $F(1, 80) = 2.28, p < .10$) and significantly greater responsivity ($F(1, 80) = 6.69, p < .01$) in NS-SCR but no differences in recovery ($F(1, 80) = 1.22$). As noted previously, there were significant differences in the racial/ethnic composition of the two groups and also variation in skin conductance measures. Repeated measures ANOVA revealed near significant differences in SCL ($F(2,79) = 2.85, p < .10$) with African American participants having the lowest SCL values at each time point and significantly reduced SCL responsivity (but not recovery). The significant Group and Time effects detected originally were relatively unchanged following removal of the 8 African American participants ($n = 2$, non pregnant; $n = 6$ pregnant). The significant race/ethnicity finding for NS-SCR ($F(2,79) = 3.19, p < .05$) was a function of lower baseline but significantly greater reactivity and recovery by Asian participants. Removal of the 12 participants of Asian ethnicity ($n = 8$ non-pregnant and $n = 4$ pregnant) preserved the original Group $\times$ Time interaction, but also resulted in significant Time ($p < .05$) and near significant ($p < .10$) Group effects suggesting that this source of NS-SCR variation, coupled with the unequal distribution across groups, provided a masking effect.

Psychological measures

The relaxation manipulation was effective in generating a subjective feeling of relaxation, as measured by the Relaxation Inventory (Time $F(1, 80) = 143.95, p < .0001$). Scores did not differ by pregnancy status nor was there a Time $\times$ Group interaction (Figure 2).

Comparisons of the subscales of the POMS collected at baseline revealed no significant differences in anxiety, depression, fatigue, or vigor, or total POMS score but pregnant women reported greater feelings of confusion than non-pregnant women ($M = 0.66$ versus $0.44, t(1,79) = 2.27, p < .01$). As might be expected, women in both groups who reported higher mood disturbance also reported lower scores on the Relaxation Inventory [rs range from $-.13$ (Fatigue scale) to $-.52$ (Anxiety scale)]. Controlling for total POMS scores did not affect overall results in the RM ANOVA for the physiological and psychological measures.

Discussion

The use of relaxation techniques to reduce stress and anxiety among pregnant women has received growing attention (Urech et al., 2010). However, the extent to which physiological and psychological effects of relaxation practices developed for non-pregnant women may transfer to pregnant populations is not well understood. For the most part, this is the result of limited knowledge of the psychophysiological processes governing normal pregnancies. Here we show that while there is no difference in the degree to which women are able to slow their breath in response to guided imagery instructions, or in the degree to which they perceive themselves to become psychologically relaxed, third trimester pregnant women exhibit blunted parasympathetic and sympathetic responsiveness as compared to non-pregnant women. Two measures best illustrate the coincident attenuation of both arms of the autonomic nervous system based on their particular sources of innervation. First, the attenuated RSA response in pregnant women, which was further attenuated when respiratory period differences were controlled, provides confirmation of reduced parasympathetic expression. Second, the lack of NS-SCR responsiveness to the manipulation, coupled with the persistently higher levels of variation in phasic modulation of this measure in the non-pregnant group, illustrates dampening of sympathetic activation. These results support the

hypothesis that prior observations that have been characterized as “stress buffering” properties during pregnancy are non-specific and instead reflect overall dampening of neural activation.

Pregnant and non-pregnant women differed in baseline physiological values such that pregnant women had faster heart rates (i.e., lower heart period), reduced RSA, and faster breathing. These findings are consistent with existing knowledge specific to the second half of gestation (Ekholm, Hartiala, & Huikuri, 1997; Gorski, 1985; Kuo et al., 2000; Stein et al., 1999). Sympathetic activation as assessed via electrodermal activity was reduced in pregnant women. This is in contrast to our earlier report on a different sample of pregnant and non-pregnant women, in which pregnant women had higher SCL levels at 24 and 36 weeks (DiPietro et al., 2005). It is possible that there are non-linear changes during pregnancy in this measure, which highlights the importance of gestational period in drawing conclusions regarding the effect of pregnancy on baseline physiological processes. The racial/ethnic differences observed in skin conductance measures did not affect the primary findings of this study related to differential responsiveness by pregnant and non-pregnant women. However, our findings echo both long-standing and more recent observations (Doberenz, Roth, Wollburg, Maslowski & Kim, 2011; Johnson & Landon, 1965) and suggest attention to sample characteristics is necessary in studies that use skin conductance.

Pregnant and non-pregnant women did not differ in the degree to which they reported that they felt relaxed at baseline or in the perceived psychological benefit of the relaxation manipulation. However, it is important to note that self-response inventories may not fully reflect psychological alterations during a study manipulation in which participants understand that they are expected to relax. In addition, there were no differences in baseline measures of mood which may have affected the relaxation response, with one exception. Pregnant women differed from their non-pregnant counterparts in reporting higher levels of confusion. Pregnancy is associated with mounting levels of confusion as gestation advances (DiPietro et al., 2005), and pregnant women routinely perceive cognitive tasks to be more difficult than non-pregnant women, even when performance between groups is equivalent (DiPietro et al., 2005; Matthews & Rodin, 1992). There is empirical support for some diminution in specific aspects of memory (e.g., verbal recall memory) in pregnant as compared to non-pregnant women (Glynn, 2010b; Henry & Rendell, 2007).

The common popular advice that pregnant women receive to engage in stress mitigation activities (Beddoe & Lee, 2008) is benign on its surface but has been offered without clear empirical rationale. Here we show that pregnant women can indeed mount a psychological and physiological relaxation response, consistent with other reports (Satyapriya et al., 2009; Urech et al., 2010), and as such may benefit from interventions designed to promote relaxation. Furthermore, induced maternal relaxation has been fairly recently shown to have consequences for fetal neurobehavior, including transient suppression of fetal motor behavior (DiPietro et al., 2008) and increases in various indicators of fetal heart rate variability (DiPietro et al., 2008; Fink et al., 2011). Alterations in relaxation responses as a result of pregnancy-related physiological changes have implications for the design and use of relaxation-based interventions with pregnant women.

Nonetheless, because pregnancy appears to be associated with blunted responsivity to exogenous influences that affect *both* challenge and relaxation responses, the significance of this phenomenon remains an open question. Glynn (Glynn, 2010a) offers the possibility that dampened maternal responsivity may be an epiphenomenon – that is, a by-product of the physiological changes required to accommodate the increasing uterine size, maintain the pregnancy and fetus, and subsequently facilitate parturition. As such, it need not offer functional significance specifically related to protecting the fetus from deleterious effects of

maternal stress exposures. The current findings cannot support or refute either supposition, but do contribute to the burgeoning literature that there is dampened maternal responsivity across a range of physiological domains to a variety of maternal experiences. A report of hyporesponsivity in pregnant women to pure tone thresholds in the lowest frequency ranges (Sennaroglu & Belgin, 2001) provides an intriguing possibility of broader pregnancy-induced sensory changes. Together, this and related findings suggest that maternal physiological adaptation is geared towards conserving the homeostasis of the intrauterine milieu and not specific to averting deleterious effects of stressful circumstances. Whether or not this serves a role in the promotion of fetal development, in the maintenance of the pregnancy, or both, remains to be seen.

Highlights

- Pregnancy is known to produce a blunted physiological response to challenge
- Pregnant women can mount physiological and psychological relaxation responses
- Pregnant women exhibit reduced autonomic, but not psychologic, responsivity to relaxation
- Blunting of physiologic responsivity during pregnancy is non-specific such that it is observed during conditions that both promote and decrease arousal

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(1a)

(1b)

(1c)

(1d)

Figure 1.

a. Mean heart period (HP) and standard error (SE) by pregnancy status from baseline through recovery. There were significant main effects for Time and Group. * indicates

significant Group $\times$ Time interactions (i.e., differences in slope) during both responsivity and recovery segments.

b. Mean skin conductance level (SCL) and standard error (SE) by pregnancy status from baseline through recovery. There were significant main effects for Time and Group. ⁺ indicates near significant ($p < .10$) Group $\times$ Time interactions during both responsivity and recovery segments.

c. Mean non-specific skin conductance response (NS-SCR) by pregnancy status from baseline through recovery. Effects for Group and Time were not significant (Time $p < .10$). * indicate significant Group $\times$ Time interaction during responsivity.

d. Mean respiratory period (RP) and standard error (SE) by pregnancy status from baseline through recovery. There were significant main effects for Time and Group but no significant Group $\times$ Time interactions.

e. Mean respiratory sinus arrhythmia (RSA) standard error (SE) by pregnancy status from baseline through recovery. There were significant main effects for Time and Group across the segments. * indicates significant Group $\times$ Time interactions during both responsivity and recovery segments.

Figure 2. Mean Relaxation Inventory scores by pregnancy status and standard error (SE) from baseline to post-relaxation. There were no differences in reports of baseline level of relaxation or group differences in the psychological relaxation response.

Table 1

Repeated Measures Analysis of Variance Assessing Physiologic Responses to Relaxation

	Group <i>F(df)</i>	Time <i>F(df)</i>	Group × Time <i>F(df)</i>
Heart Period (HP)	$F(1,80) = 49.51^{**}$	$F(2, 160) = 97.67^{**}$	$F(2, 160) = 12.86^{**}$
Skin Conductance Level (SCL)	$F(1, 80) = 6.59^*$	$F(2, 160) = 42.00^{**}$	$F(2, 160) = 1.64$
Non-specific Skin Conductance Responses (NS-SCR)	$F(1, 80) = .33$	$F(2, 160) = 2.73$	$F(2, 160) = 4.07^*$
Respiratory Period (RP)	$F(1, 74) = 7.51^*$	$F(2, 148) = 31.43^{**}$	$F(2, 148) = 0.56$
Respiratory Sinus Arrhythmia (RSA)	$F(1, 73) = 28.45^{**}$	$F(2, 146) = 29.05^{**}$	$F(2, 146) = 5.24^*$
Respiratory Sinus Arrhythmia (RSA) controlling for RP	$F(1, 72) = 21.30^{**}$	$F(2, 146) = 8.57^{**}$	$F(2, 146) = 8.58^{**}$

* $p < 0.01$;** $p < 0.001$