

## MODELING THE TYPES AND TIMING OF STRESS IN PREGNANCY

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In the current study we examined whether or not stress at critical intervals during pregnancy, or stress consistently experienced across the course of pregnancy was associated with gestational age in a (large) multiethnic sample. After deriving a latent trait-state model of stress, we examined whether or not particular components of stress (i.e., perceived stress, general anxiety, pregnancy-specific anxiety), or stress in general, at specific time points or over time were associated with gestational age. Pregnancy-specific anxiety over the course of pregnancy was associated with shorter gestation after controlling for a number of risk factors, including history of diabetes, smoking, maternal age, and parity. Moreover, these findings suggest that the relation between pregnancy-specific anxiety and gestational age was similar across ethnic groups. The importance of modeling the components and timing of stress with latent variable methodology is discussed.

*Keywords:* Stress; Modeling; Latent variables; Pregnancy; Gestational age

Research in the last two decades has shown that stress results in psychological and biological changes that may place persons at risk for health problems (Cohen *et al.*, 1995). These findings may be limited, however, due to the vast differences in how researchers operationalize stress. The measurement of stress ranges from dispositional indicators (e.g., trait anxiety) to environmental indicators (e.g., life events) to perceptual indicators (e.g., perceived stress) and include response-based indicators (e.g., generalized distress) of stress (Cohen *et al.*, 1995, Lobel and Dunkel-Schetter, 1990). The similarities and differences among these measures of stress (components) are not well understood. A good first step is to conceptualize stress as a multidimensional construct in which the commonalities of these various components of stress are explicitly modeled. That is, the commonality among the measures of these stress components potentially represents the “best” operational definition of stress. In the current study, we introduce a statistical model of stress that provides a framework from which the conceptual similarities among some of these components (measures) of stress can be tested and ultimately used to predict outcome variables. Moreover, this model allows researchers to examine the complex interrelationships between these components

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of stress and the modeling of stress constructs over time. Specifically, we examined the dynamic and stable properties of stress in the context of pregnancy.

A growing literature suggests that prenatal stress is associated with preterm delivery and shorter gestation (see Dunkel-Schetter *et al.*, 2000; Hoffman and Hatch, 1996; Lobel, 1994; Paarlberg *et al.*, 1995 for reviews; however, see e.g., Hoffman and Hatch, 2000), although not all studies have demonstrated this relationship (cf., Peacock *et al.*, 1995). However, numerous issues that are key to clarifying these results remain understudied and unresolved. Here we consider (1) critical periods of vulnerability in the effects of stress during pregnancy and (2) particular components of stress that influence birth outcomes. Pregnancy is characterized by dynamic changes in both psychological and biological (e.g., neuroendocrine parameters) processes, and thus it is curious that researchers have largely ignored issues such as timing, sequence, and duration with respect to the pregnancy process. Moreover, it is unclear whether specific components of stress (e.g., life events, perceived stress, general anxiety, or pregnancy-specific anxiety) or stress in general (a composite of these stress measures) is a better predictor of birth outcomes.

The timing of stress in pregnancy has potentially profound implications for birth outcomes, but this issue is not well studied in humans (Dunkel-Schetter *et al.*, 2000; Wadhwa *et al.*, 1993). There is some evidence to suggest that stress late in pregnancy (third trimester), in comparison to early prenatal stress (second trimester), is more predictive of preterm delivery (see Hedegaard *et al.*, 1993). Others, however, have found that stress during late second trimester and early third trimester was associated with decreases in gestational age (Rini *et al.*, 1999; Wadhwa *et al.*, 1993). Still others have found that increased stress at a single time point in the second trimester was associated with an increased risk of preterm delivery (Zambrana *et al.*, 1997). It is quite possible that stress experienced throughout the course of pregnancy could also impact birth outcomes in a cumulative manner. Schneider and Coe (1993) have found that infant monkeys born to mothers exposed to stress throughout the course of pregnancy, in comparison to mothers who were exposed to one stressful event in midpregnancy, have infants with poorer motor abilities and more neuromotor problems. Because the overwhelming majority of stress and pregnancy studies have used cross-sectional rather than longitudinal designs (Lobel, 1994), meaningful comparisons of the effects of stress at different time points and across time points during pregnancy have been lacking.

As noted earlier, stress has been operationalized in pregnancy studies by a myriad of measures including various life events scores, perceived stress, trait anxiety, state anxiety, pregnancy-specific anxiety, and generalized distress. The majority of past research, however, has used measures of life event stress, trait anxiety, and state anxiety (see Lobel, 1994). Much of this past research suffers from methodological weaknesses and as a result the relation between stress and birth outcomes disappears when controlling for demographic variables and medical risk (Lobel, 1994). More recently, methodologically rigorous studies have found relations between specific *components* of stress and birth outcomes. For example, Wadhwa *et al.* (1993) found that fear of labor and fear of pregnancy outcome (indicators of pregnancy-specific anxiety) predicted shorter gestation, and Hedegaard *et al.* (1993) have shown that general distress is associated with shorter gestation and preterm delivery. The results of these and past studies suggest that the predictive ability of stress is dependent on the particular stress measure employed (see Lobel, 1994; Rini *et al.*, 1999).

A promising approach involves the use of a multidimensional representation of general stress that incorporates the commonality among indicators of environmental (e.g., life events), perceptual (e.g., perceived stress), and response-based (e.g., anxiety) definitions of stress. These factors are being used with increasing frequency, and some researchers have begun to incorporate *latent* stress factors using structural equation modeling (e.g., Lobel and Dunkel-Schetter, 1990). Use of latent stress factors allows one to capture the common variance among indicators of stress (i.e., to develop a measurement model). A handful of studies have examined stress-birth outcome relations using latent representations of stress. Lobel *et al.*, (1992) defined stress using measures of chronic state anxiety, chronic perceived stress, and life event distress; this stress factor was a significant predictor of earlier delivery and lower birthweight. Zambrana *et al.* (1997) used measures of life events, life event distress, and perceived stress as indicators of stress, and this factor predicted shorter gestation in a cohort of 900 Mexican and Mexican-American women. Finally, Rini *et al.* (1999) used measures of state anxiety, fear of labor and delivery, and fear of pregnancy outcomes as indicators of stress, and this factor too predicted shorter gestation.

This latent variable methodology used in stress and pregnancy research, however, is not without problems. First, observed indicators of a latent stress factor vary from study to study and thus the latent stress factors, and the relations between these factors and birth outcomes, may not be directly comparable. Lobel *et al.* (1992) found that measures of perceived stress, state anxiety, and distress but *not* life event stress were indicative of a latent stress factor, whereas Zambrana *et al.* (1997) used life events, life event distress, and perceived stress as indicators of stress. Moreover, the indicators of stress used by Rini *et al.* (1999) did not overlap with the indicators used in the previous two studies. Second, these studies have not reported in full the unique relations between latent factors for the specific components of stress (e.g., perceived stress, anxiety, life events) and birth outcomes. Third, the factorial validity of stress constructs across ethnic groups has not been well established. Rather than assuming that stress is comparable across ethnic groups, the measurement properties should be examined such that cross-ethnic measurement equivalence precedes substantive comparisons between these groups.

In order to test for the possible impact of the nature of stress (i.e., general stress vs. components of stress) and the timing of stress (i.e., at specific time points vs. across time points), prospective longitudinal designs have been proposed. More recently, specific statistical models such as the latent trait-state model (LTS; e.g., Dumenci and Windle, 1996; Kenny and Zautra, 1995; Schmitt and Steyer, 1993) have been developed to assess these complex relations. Subsumed within the LTS model, latent factors representing various combinations of the nature and timing of stress can be derived. First, a factor representing general stress across time points can be created (referred to as *trait*<sup>1</sup> stress). Second, a factor representing general stress at each time point can be created (referred to as *state* stress). Third, factors representing specific components of stress across time points can be created (referred to as *trait-specific*<sup>2</sup> stress). Once these factors are

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<sup>1</sup> The term *trait* is not used in its traditional sense here. It does *not* refer to a stable personality characteristic as typically espoused by personality theorists. Rather, *trait* in this context refers to the cross-situational consistency with which one has responded on a state measure.

<sup>2</sup> See footnote 1.

derived, conventional confirmatory factor-analytic techniques are used to exam the validity of the measurement models.

A more detailed presentation of modeling longitudinal data in general and the LTS model in particular follows. We assessed stress with three different measures (Perceived Stress Scale [PSS], State Anxiety Inventory [STA], Pregnancy-Specific Anxiety Scale [PSA] at three different occasions during pregnancy. The first longitudinal model is referred to as the General State Stress Model (see Fig. 1). In this model the commonality of each stress measure at a specific time point is modeled (i.e., the commonality of perceived stress, state anxiety, and pregnancy-specific anxiety at Time 1, Time 2, and Time 3, respectively). These latent state factors, then, represent labile aspects of stress measures at each assessed point during the course of pregnancy. The second longitudinal model is referred to as the General Trait-State Stress Model (see Fig. 2). This model is represented by the general state stress factors from the previous model as well as a trait component that represents the dispositional nature of the stress measures (i.e., the commonality of perceived stress [PSS], state anxiety [STA], and pregnancy-specific anxiety [PSA] across the three time points). The third longitudinal model is referred to as the Trait-Specific Stress Model (see Fig. 3). This model is represented by a trait-specific component of stress that represents the dispositional but unique aspects of the individual stress measures (i.e., the commonality of perceived stress at Time 1, Time 2, and Time 3; and analogously for state anxiety and pregnancy-specific anxiety). By incorporating trait, trait-specific, and state factors into a single model, the LTS Model is realized (see Fig. 4). The previous models, then, are variants, and are actually subsumed within the broad framework of the LTS Model. Thus, each of these models (and other variants) was examined to determine which model best represents stress across time. Once the “best-fitting” model has been identified, the

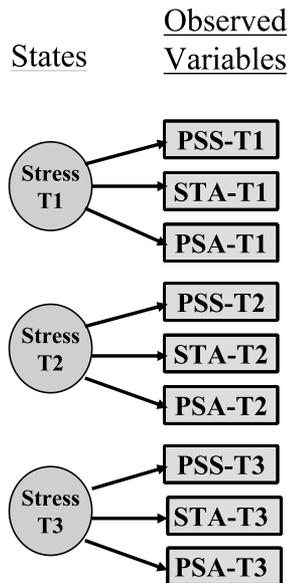


FIGURE 1 General state stress model. PSS = Perceived Stress Scale; STAI = State Anxiety; PSA = Pregnancy-Specific Anxiety. Error terms are omitted for clarity.

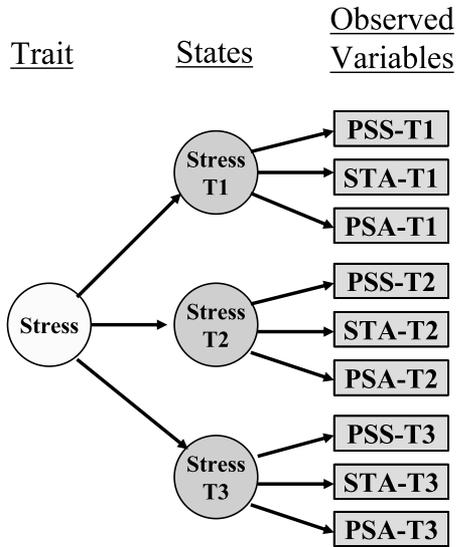


FIGURE 2 Trait-state model for general stress. PSS = Perceived Stress Scale; STAI = State Anxiety; PSA = Pregnancy-Specific Anxiety. Error terms are omitted for clarity.

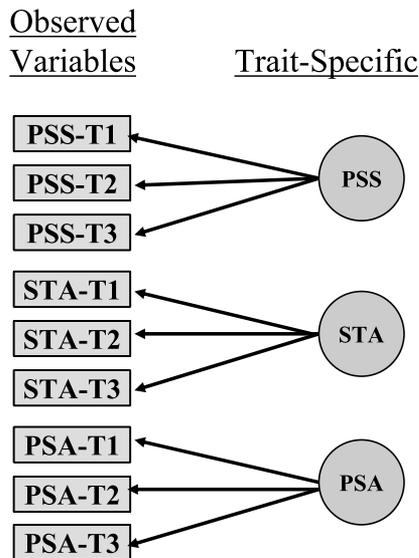


FIGURE 3 Trait-specific stress model. PSS = Perceived Stress Scale; STAI = State Anxiety; PSA = Pregnancy-Specific Anxiety. Error terms are omitted for clarity.

latent factors of this model can be incorporated into a larger structural equation model to predict outcome variables, such as gestational age in pregnancy research.

The average length of gestation for pregnancy is 40 weeks, but babies who are born before 37 weeks completed gestation are more prone to neonatal complications. The risk increases as the duration of gestation decreases. Therefore, identifying variables associated with shorter gestation and preterm delivery is vitally important in reducing

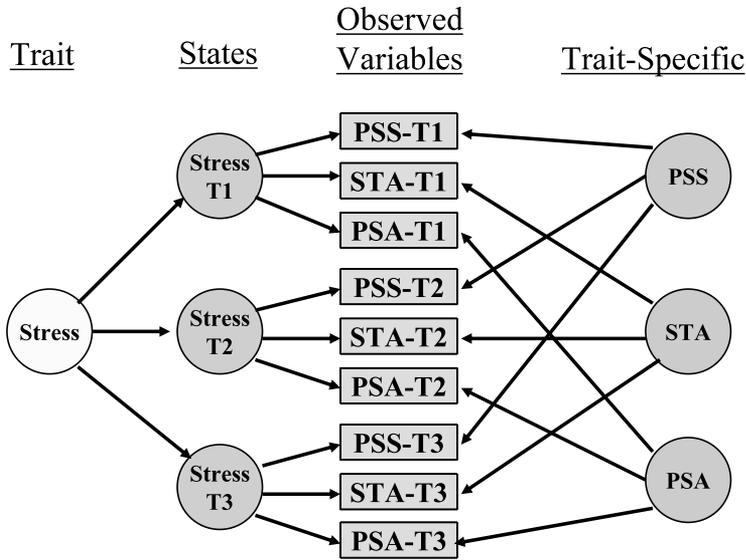


FIGURE 4 Full latent trait-state model for stress. PSS = Perceived Stress Scale; STAI = State Anxiety; PSA = Pregnancy-Specific Anxiety. Error terms are omitted for clarity.

indices of child morbidity and mortality as well as health care costs. This is particularly important in socioeconomically and racially disadvantaged women who have a higher incidence of infant mortality and morbidity and shorter gestations (see, e.g., Flack *et al.*, 1995). Moreover, these individuals experience both a greater number of stressful events and increased levels of distress (Seguin *et al.*, 1999).

Because psychosocial stress was linearly related to gestational age in past studies, and because high stress is hypothesized to be a risk factor for preterm delivery, gestational age was used as the focal birth outcome. Using the factors derived from the LTS model, we examined the nature and the timing of the relations between prenatal stress and gestational age. First, we evaluated whether trait, trait-specific, or state factor structures of stress best represented the data. We hypothesized that the full LTS model would best represent the stress measures. That is, we predicted that there would be enough commonality among the stress measures to develop a latent construct of general stress. However, we further predicted that there would be enough unique variance associated with each individual stress measure that latent factors that were trait-specific would be equally plausible. Second, we tested the relations between the stress factors of the best-fitting LTS model and gestational age. These relations were assessed after controlling for known risk factors. We hypothesized that general stress and each trait-specific stress factor would predict shorter gestations. Third, we simultaneously examined whether or not (a) the measurement properties of three stress instruments (PSS, STAI, PSA) were equivalent (i.e., cross-ethnic measurement equivalence) and (b) the stress-gestational age relation was consistent across three ethnic groups (cross-ethnic structural equivalence). Some researchers (e.g., Hoffman and Hatch, 1996) have suggested that United States ethnic groups experience stress to different degrees and that this could influence the magnitude of stress-birth outcome relations in some groups. Therefore, we hypothesized that stress-gestational age relations would be

stronger for both African-Americans and Latinas in comparison to Nonhispanic Whites.

## METHOD

### Recruitment and Study Participants

Participants consisted of a large sample of pregnant women ( $n = 688$ ) recruited from a health maintenance organization and a public clinic and private suites of a major metropolitan hospital in Los Angeles before their 20th week gestation. The larger study involved three prepartum interviews and three prepartum administrations of standardized psychological instruments, along with assessments of medical records for birth outcomes and physiological measures.

Patients that were less than 18 years of age ( $n = 17$ ), had a stillborn birth ( $n = 6$ ), had a multiple gestation birth ( $n = 3$ ), quit after consenting to participate ( $n = 26$ ), did not have outcome (i.e., gestational age) data ( $n = 53$ ), or did not have complete psychosocial data ( $n = 165$ ) were excluded from the analysis. Four hundred and eighteen patients had complete birth outcome data and psychosocial data at all three time points, and comprised the analysis sample. When the analysis sample was compared to the group of individuals who quit after consenting to participate, did not have gestational age data, or did not have complete psychosocial data, few significant differences were found. With respect to demographic variables and sample characteristics, the individuals who dropped out of the study were significantly older than the analysis sample ( $M = 28.81$  vs.  $M = 27.73$ ;  $p = 0.02$ ). However, the analysis sample had significantly ( $p < 0.05$ ) longer gestational ages ( $M = 39.56$  vs.  $M = 38.02$ ), experienced less state anxiety at time 1 ( $M = 2.15$  vs.  $M = 2.33$ ), perceived stress at time 2 ( $M = 2.34$  vs.  $M = 2.50$ ), and pregnancy-specific anxiety at time 2 ( $M = 2.68$  vs.  $M = 3.02$ ).

The 418 patients for the analysis sample were comprised of 178 African-Americans (42.6%), 145 Latinos (34.7%), and 95 Nonhispanic Whites (22.7%). The sample was of low to moderate education level ( $M = 13.08$  years of education,  $SD = 2.35$ ), equally split on marital status (49.3% married and 50.7% single [either separated, divorced, or widowed]), and their mean annual family income was relatively low to moderate (24.4% < \$10,000; 35.2% \$10,000 to \$30,000; 17.9% \$30,001 to \$50,000; 22.5% > \$50,000). Medical data was obtained from medical records prenatally and after the delivery. With respect to parity, 37.6% of the patients were nulliparous (first delivery) and 62.4% were multiparous (previously delivered). The mean gestational age at birth was 39.56 weeks (range = 35.71 to 42.43;  $SD = 1.30$ ). The large majority (95.5%) of the analysis sample delivered at term.

### Measures

**Medical Risk** A number of medical risk factors were examined in the current study. Thirty-seven conditions that tapped various risk factors were developed, based on previous research (e.g., Lobel *et al.*, 1992, Zambrana *et al.*, 1997). These included items from past obstetric/gynecological history (e.g., history of infertility), past medical history (e.g., diabetes), current pregnancy risk factors (e.g., incompetent cervix), and intrapartum complications (e.g., pyrexia). The most frequently occurring medical

conditions included women who had anemia (29.9%), vaginal infection (28.2%), history of gynecological surgeries (24.2%), flu syndrome (20.3%), low weight gain during the second trimester (20.1%), vaginal bleeding (19.6%), urinary tract infection (18.2), low body mass index (12.9%), pulmonary problems (11.3%), fever in pregnancy (10.2%), uterine anomaly (6.7%), previous preterm births (6.5%), hypertension (4.3%), and history of diabetes (3.8%). In addition, life style factors were also considered. Only 4.3% of the sample was currently smoking.

*Perceived Stress (PSS)* An 8-item abbreviated version of the Perceived Stress Scale was administered to assess general feelings of stress during pregnancy (Cohen *et al.*, 1983). This scale measures the perceived unpredictability and uncontrollability of general stress. Specifically, this scale asks how often in the last month subjects were unable to control important things in their life, deal with daily hassles, cope with life changes, handle personal problems, control irritations, and overcome difficulties; they were also asked how often they felt that things “were not going well” and how often they were “not on top of things.” This instrument has been used in several studies with pregnant women (e.g., Lobel *et al.*, 1992; Moore *et al.*, 1991; Wadhwa *et al.*, 1993). Responses were provided on a scale ranging from *never* (= 1) to *almost always* (= 5). This scale was administered at the three time points. The mean, standard deviation, and Cronbach alpha coefficients for each time point were: (a) Time 1 ( $M = 2.44$ ;  $SD = 0.59$ ;  $\alpha = 0.81$ ), (b) Time 2 ( $M = 2.34$ ;  $SD = 0.61$ ;  $\alpha = 0.84$ ), and (c) Time 3 ( $M = 2.24$ ;  $SD = 0.64$ ;  $\alpha = 0.86$ ).

*State Anxiety (STAI)* A 10-item shortened version of the State-Trait Anxiety Inventory was used to assess subjective feelings of anxiety (Spielberger, 1983). This version of the instrument is psychometrically sound, can be used on repeated occasions, and has been used in previous pregnancy studies (see Istvan, 1986). Subjects are presented with a list of adjectives and asked to describe their feelings in the last few days. These adjectives include *nervous*, *tense*, *jittery*, and *frightened*. Responses were provided on a scale ranging from *not at all* (= 1) to *very much always* (= 4). This scale was administered at the three time points. The mean, standard deviation, and Cronbach alpha coefficients for each time point was: (a) Time 1 ( $M = 2.14$ ;  $SD = 0.57$ ;  $\alpha = 0.85$ ), (b) Time 2 ( $M = 1.97$ ;  $SD = 0.56$ ;  $\alpha = 0.86$ ), and (c) Time 3 ( $M = 2.02$ ;  $SD = 0.56$ ;  $\alpha = 0.87$ ).

*Pregnancy-Specific Anxiety (PSA)* Four pregnancy-specific anxiety items were derived from a factor analysis of a larger pool of items that asked about pregnancy-specific affective states. Before responding to the mood adjectives, subjects were prompted that they would be talking about “how they have felt about being pregnant” in the past week. Specifically, subjects were asked to indicate how often they had felt *anxious*, *concerned*, *afraid*, and *panicky* in the past week. Responses were provided on a scale ranging from *not at all* (= 1) to *very much* (= 5). These four items were similar to items from the STAI except they referred explicitly to this pregnancy and were context-specific. These items were administered at the three time points. The mean, standard deviation, and Cronbach alpha coefficients for each time point was: (a) Time 1 ( $M = 2.82$ ;  $SD = 0.88$ ;  $\alpha = 0.72$ ), (b) Time 2 ( $M = 2.65$ ;  $SD = 0.88$ ;  $\alpha = 0.71$ ), and (c) Time 3 ( $M = 2.80$ ;  $SD = 0.83$ ;  $\alpha = 0.67$ ).

## Procedure

Participants were assessed on three occasions during the second and third trimester of pregnancy: Time 1 ( $M = 18.39$  weeks,  $SD = 4.41$ ), Time 2 ( $M = 27.88$  weeks,  $SD = 3.29$ ), and Time 3 ( $M = 35.80$  weeks,  $SD = 3.39$ ). During each assessment, participants completed questionnaires and then were interviewed in either English or Spanish by a trained interviewer. Sociodemographic data was collected at the first time period; the three stress measures were collected at all three time points; and the medical data was collected during and after pregnancy.

## RESULTS

### Model Testing Strategy<sup>3</sup>

Model testing was conducted in three phases. First, a series of LTS models was assessed to determine which factors (i.e., trait, trait-specific, and state) best represented the stress data. Once the “best-fitting” model was determined, gestational age was added to the model in phase 2 as the outcome variable. Also added at this step were direct paths from seven control variables (maternal age, years of education, annual family income, nulliparity, marital status, smoking behavior, and history of diabetes)<sup>4</sup> to gestational age and each stress factor.<sup>5</sup> In phase 3, a multigroup analysis was performed to examine the invariance of the factor loadings and factor variances/covariances (i.e., to establish cross-ethnic measurement equivalence) and the stress-gestational age paths across the three ethnic groups (to establish cross-ethnic structural equivalence). In all analyses, each stress index at each time point (e.g., PSS-Time 1) was used as an observed variable; there were nine observed stress variables.

### Models to be Tested

In phase 1 of the data analysis, eight specific LTS models were tested and compared. Model 1 was the general LTS model represented by Fig. 4. The second model tested was the null or independence model, which specifies no relations among the observed variables. Model 3 was the General Stress Model, which specifies paths from a general stress factor to the nine observed variables; the individual stress measures at all three time points were hypothesized to load on the same stress factor. Model 4 tested the General State Stress Model in which factors were constructed to represent general state stress at time 1, time 2, and time 3 (see Fig. 1). Model 5 was the General Trait-State

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<sup>3</sup> Life events were measured in this study but were not modeled because of low correlations with the three other measures of stress (all  $r$ s  $< 0.15$ ). Moreover, these correlations varied by ethnicity further complicating the development of creating one latent stress factor with the four observed variables.

<sup>4</sup> Maternal age, years of education, and annual family income were entered into the model as continuous variables. Marital status, nulliparity, smoking, and history of diabetes were dummy coded and entered into the model. Smoking was significantly associated with STA-Time 2,  $r(417) = .10$ ,  $p < 0.05$  and STA-Time 3,  $r(417) = 0.12$ ,  $p < 0.05$ , whereas a history of diabetes was significantly related to gestational age,  $r(417) = -0.19$ ,  $p < 0.05$ . Because of these relations, we controlled for these two medical risk factors in models predicting gestational age.

<sup>5</sup> In order to completely partial out the impact of the seven control variables, one must also specify associations between the residuals of the stress factors and gestational age. We thank an anonymous reviewer for emphasizing this point.

Stress Model; this model is identical to Model 4 with respect to the construction of the state stress factors, but a trait stress factor which specified a path from this general trait (second-order) factor to each of the three general state factors was also specified (see Fig. 2). Model 6 was the Trait-Specific Stress Model; these factors were formed by using each time point as an indicator of its trait-specific factor (e.g., PSS-Time 1, PSS-Time 2, and PSS-Time 3 were indicative of the trait-specific PSS latent factor; and analogously for the STAI and the PSA. (see Fig. 3). Model 7 was the Trait-Specific and State Stress Model; this model was identical to Model 4 with respect to the general state factors, but three trait-specific factors from Model 6 were incorporated into the measurement model. Finally, Model 8 was the Correlated Factors Trait-Specific Model. This model is identical to Model 6 with the addition of correlations among PSS, STAI, and PSA latent factors.

### Main Analyses

The zero-order correlations among the stress variables are presented in Table 1. There were significant positive correlations for the trait-specific correlations over time points: among (a) PSS-Time 1, Time 2, Time 3; (b) STAI-Time 1, Time 2, Time 3; and (c) PSA-Time 1, Time 2, Time 3. There were also significant positive correlations for the state correlations: among (a) Time 1 PSS, STAI, and PSA; (b) Time 2 PSS, STAI, and PSA; and (c) Time 3 PSS, STAI, and PSA. However, the magnitude of the correlations between the PSS and PSA at each time point was much smaller than that of the PSS or PSA with the STAI.

For each model, covariance matrices were estimated with maximum likelihood estimation via EQS (Bentler, 1992). To test the fit of each model, the  $\chi^2$  likelihood ratio test was used. However, because this test is dependent on sample size, the comparative fit index (CFI; Bentler, 1990) and the root measure square residual (RMSR; see Hu and Bentler, 1999) were used as indices of descriptive fit. As suggested by Bentler, CFI values greater than 0.93 were used as indicators of well-fitting models. RMSR values of less than 0.08 were used as indicators of well-fitting models (Hu and Bentler, 1999).

A summary of the LTS models is presented in Table 2. The full LTS model (Model 1) fit well according to the descriptive fit index, however, one parameter was constrained at its lower bound and two parameters were linearly dependent on other parameters of the model. These conditions are indicative of poor-fitting models (see Bentler, 1992).

TABLE 1 Correlations among Perceived Stress, State Anxiety, and Pregnancy-Specific Anxiety

Variable	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) PSS-Time 1	<b>0.64*</b>	<b>0.61*</b>	0.43*	0.39*	0.40*	0.20*	0.15*	0.18*
(2) PSS-Time 2		<b>0.60*</b>	0.38*	<u>0.52*</u>	0.41*	0.17*	0.17*	0.20*
(3) PSS-Time 3			0.35*	<u>0.41*</u>	<u>0.53*</u>	0.26*	<u>0.21*</u>	<u>0.29*</u>
(4) STAI-Time 1				<b>0.60*</b>	<b>0.50*</b>	0.47*	0.33*	0.32*
(5) STAI-Time 2					<b>0.59*</b>	<u>0.37*</u>	0.45*	0.40*
(6) STAI-Time 3						0.33*	0.31*	0.45*
(7) PSA-Time 1							<b>0.56*</b>	<b>0.56*</b>
(8) PSA-Time 2								<b>0.68*</b>
(9) PSA-Time 3								

Note: Trait-specific correlations are presented in bold; state correlations are underlined. PSS = Perceived Stress Scale; STAI = State Anxiety; PSA = Pregnancy-Specific Anxiety.

\* $p < 0.01$ .

TABLE 2 Indices of fit for each model

Model		$\chi^2$	df	CFI	RMSR
1.	Full LTS Model <sup>1</sup>	31.87	15	0.99	0.03
2.	Null Model	1761.84	36	0.00	0.38
3.	General Stress Model	602.01	27	0.67	0.12
4.	General State Stress Model	1113.98	27	0.37	0.34
5.	General Trait-State Stress Model	596.90	24	0.67	0.13
6.	Trait-Specific Stress Model	452.11	27	0.75	0.25
7.	Trait-Specific and State Stress Model	269.29	18	0.86	0.27
8.	Correlated Factors Trait-Specific Stress Model	149.65	24	0.93	0.04

<sup>1</sup>Condition codes were given for this model, which is indicative of poor fit. CFI = comparative fit index. RMSR = root mean square residual.

Models 2 through 7 also fit poorly (all CFIs well below 0.90). Model 8, however, fit well according to the descriptive indices. Moreover, this model fit significantly better than Model 7,  $\Delta\chi^2(6, N = 418) = 119.64, p < 0.05$ , which was the “best-fitting” of the previous models. As shown in Fig. 5, all of the factor loadings and factor correlations for this model were large, positive, and significant ( $p < 0.05$ ). The factor correlations between the PSS and STA, and between the PSA and the STA were particularly strong. The factor correlation between the PSS and PSA was much smaller, suggesting that there is less similarity between these two measures of stress.

In phase 2 of the model analyses, direct paths from the latent trait-specific factors of Model 8 and the seven control variables to the outcome gestational age were specified. The trait-specific effects of the PSS, STAI, and PSA on gestational age were of substantive interest. Overall, this model fit reasonably well,  $\chi^2(57, N = 418) = 203.34, p < 0.05, CFI = 0.92, RMSR = 0.04$ . However, only the PSA had a significant effect on gestational age ( $\beta = -0.17, p < 0.05$ ). Patients who reported higher levels of pregnancy-specific anxiety had shorter gestations. Neither PSS ( $\beta = -0.01, p > 0.05$ )

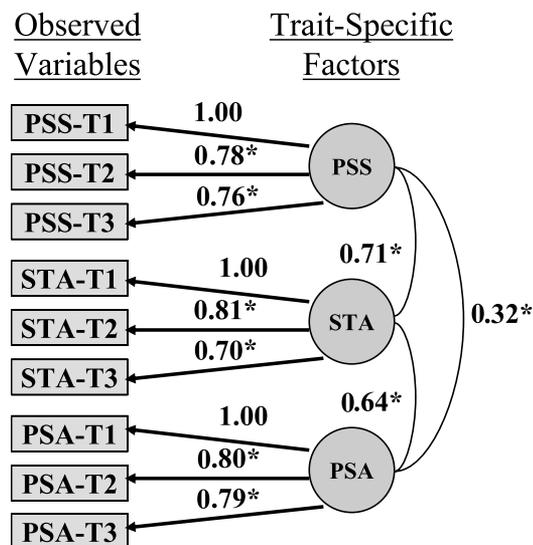


FIGURE 5 Trait-specific model of stress with correlated factors. Factor loadings and path coefficients are standardized (\* $p < 0.05$ ). Error terms are omitted for clarity.

nor STAI ( $\beta = 0.07$ ,  $p > 0.05$ ) were significantly associated with gestational age when all other relations were controlled for. The factor loadings and factor correlations remained significant ( $p < 0.05$ ) as shown previously in Fig. 5. In addition, among the control variables, only the history of diabetes variable was significantly related to gestational age ( $\beta = -0.13$ ,  $p < 0.05$ ), suggesting that individuals with a history of diabetes had shorter gestations.

In phase 3 of the model analyses, the invariance (equivalence) of the factor loadings, factor variances/covariances, and the stress-gestational age path across the three ethnic groups was simultaneously tested. The overall model continued to fit reasonably well,  $\chi^2(372, N = 418) = 501.28$ ,  $p < 0.05$ , CFI = 0.90, RMSR = 0.05. The *unstandardized* factor loadings (ranged from 0.96 to 1.17), factor variances (ranged from 0.49 to 0.63) and factor covariances (ranged from 0.17 to 0.38) were significant and equivalent across ethnic groups.<sup>6</sup> The structural path from PSA to gestational age increased slightly in magnitude (unstandardized path coefficient =  $-0.18$ ), remained significant ( $p < 0.05$ ), and was invariant across the three ethnic groups ( $p > 0.05$ ). The structural paths from PSS and STA to gestational age, respectively, remained nonsignificant but were invariant across the three ethnic groups.

## DISCUSSION

The results of the current study add to the growing body of literature indicating that maternal stress is an independent predictor of gestational age. Using a relatively new application of latent variable methodology, the results of this study extend existing findings by showing that specific components of stress (rather than general stress) and stress experienced at multiple time-points across the course of pregnancy are predictive of gestational age. Specifically, pregnancy-specific anxiety (and *not* perceived stress or state anxiety) experienced over the course of pregnancy was associated with shorter gestation after controlling for known risk factors. Moreover, both the measurement and substantive relations were invariant across three major ethnic groups (African-Americans, Latinos, non Hispanic Whites).

While previous stress and pregnancy studies have used a variety of specific composite measures of stress (see Lobel, 1994) or latent factors of general stress (e.g., Zambrana *et al.*, 1997) to predict birth outcomes, the current study developed a latent factor and a stress composite representing a pregnancy-specific anxiety component of stress, which was predictive of gestational age. This finding is consistent with previous research using indices of pregnancy-specific anxiety (Rini *et al.*, 1999; Wadhwa *et al.*, 1993). In these and the current study, pregnancy-specific anxiety represented a phenomenological stress factor (i.e., primarily affect) that is consistent with response-based definitions of stress (see Lobel and Dunkel-Schetter, 1990). Mothers' concerns about their own health, their baby's health, and the anticipated pain of labor and delivery are all indicative of these anxieties about the pregnancy and are predictive of birth outcomes.

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<sup>6</sup> The Lagrange Multiplier test was used to evaluate the invariance of model parameters across groups. Probability levels *greater* than the traditional 0.05 were used as indicators that a target parameter was invariant across ethnic groups.

Whether the origins of the anxiety are intrapsychic or based on the facts of pregnancy or both is not known.

Beyond the components of stress issue, the timing of stress in predicting gestational age was tested with stress across the course of pregnancy. That is, stress beginning as early as 18 weeks gestation and continuing through the third trimester (as represented by the trait-specific factor) was associated with shorter gestation. This finding suggests that stress experienced consistently across the course of pregnancy is a good predictor of gestational age. Methodologically this suggests that more complex multivariate and longitudinal models of the stress process need to be incorporated into health and medical research. However, a substantive comparison could not be made between the predictive ability of the trait-specific factor representing stress and a model that includes state stress, as the factors representing the latter did not fit well.

As the results of this study show, using latent stress factors and the LTS model has important empirical and conceptual benefits. Latent factors explicitly model the “common” variance of stress measures while relegating irrelevant variance (both systematic and random) to the error term, so that this error does not impact substantive predictions. This approach conceptually and empirically enhances not only the measurement of stress, but also the associations between stress factors and other target factors or variables. In the current study, there were no significant zero-order correlations between the individual stress variables and gestational age. Moreover, when a pregnancy-specific anxiety composite was created by simply averaging PSA scores across the three time points, the relation between pregnancy-specific anxiety and gestational age was not significant. However, when the commonality among pregnancy-specific anxiety at Time 1, Time 2, and Time 3 was modeled in the form of a latent factor, the pregnancy-specific anxiety significantly predicted gestational age. By forming this latent factor, the pregnancy-specific anxiety and gestational age relation is disattenuated from measurement error and thus this relation is a good approximation of the “true” population value (see Bollen, 1989). If a latent stress factor had not been used, we would have concluded that a significant relation was not evident, when in actuality this relation was underestimated due to error variance. This latter conclusion would have been misleading.

The value of latent factors is further realized when incorporated into LTS models. The LTS model provides a broader conceptualization of how stress is defined and how it operates at single and over multiple time points. From this model, latent factors that represent general stress at specific time points, general stress across time points, and stress components across time points can be created. Thus, the conceptual similarity and dissimilarity between measures of stress can be explicitly compared. From this comparative analysis, the “best” representation of stress can be statistically determined. Once this representation is determined, the stress factors from this model can be assessed for their predictive ability with respect to birth outcomes or health-related variables in general.

It is of considerable interest that the full LTS model did not fit well in the current study. In short, in the full LTS model the extraction of state factors failed because of (a) the high correlation among the measures of the three trait-specific factors and (b) the low correlations between the individual measures of perceived stress and pregnancy-specific anxiety at each time-point. With respect to the former, the three individual stress measures were strongly correlated with their own measure over time (see Table 1).

However, the correlation between the measures of perceived stress and pregnancy-specific anxiety at each time-point was low, thus making it difficult for the general state factors in the full LTS model to be correctly specified. Moreover, the second-order general trait stress factor had very little variance to predict in the already misspecified state factors. The trait-specific variation of the LTS model does, however, capture stress for our target population. The stress that this population experienced, while response-based, is specific to the anxieties that pregnant women experience. The general perceptions of stress (as measured by the Perceived Stress Scale) and their general feelings of anxiety (as measured by the State Anxiety Scale) appear to be secondary and weakly related to the concerns that they have about the birth of their child.

As usual, this study's results have methodological and substantive limitations. First, the indices of stress were appraisal- and emotion-based. While we attempted to incorporate a life events measure in modeling the general stress factor, the associations with measures of perceived stress, state anxiety, and pregnancy-specific anxiety were exceedingly low. Thus the life events or environmental component of stress was not part of the final analyses. Clearly more research to establish the factorial validity of latent stress measures is needed. It should be noted, however, that some researchers (see Cohen *et al.*, 1995) believe that environmental stressors are theoretically-distinct from response-based measures of stress, and therefore should not be modeled as measures of the same latent variable.<sup>7</sup>

Second, on a substantive level, the small percentage of women who delivered preterm (only 4.5% of the women;  $n = 19$ ) precluded us from running the LTS models on this dichotomy. Thus the clinical significance of the findings cannot be determined. Finally, while we controlled for a number of demographic variables, sample characteristics, and medical risk factors, it might be the case that lifestyle factors could also explain shorter gestations. We did, in fact, control for smoking in the current study, but other lifestyle factors such as physical activity and alcohol/drug could also be related to gestational age. Our results could also be biased due to the exclusion criteria imposed in the current study. There were significant differences between the analysis sample and women who were excluded. These differences included significantly longer gestational ages for the analysis sample and significantly lower stress levels for the excluded women. The results of this study should be viewed with caution in light of these findings.

In conclusion, this study highlights the importance of studying specific time periods during which stress may influence birth outcomes and the particular components of stress that influence these outcomes. By incorporating latent factors representing the timing aspects of stress and the various components of stress, a clearer model of the stress and pregnancy model can be developed. In addition, other known risk factors can be incorporated within the framework of these models. Using LTS methodology, we were able to show that women who experience higher levels of pregnancy-specific anxiety (rather than general stress, perceived stress, or state anxiety) across their pregnancy (rather than at critical time points during pregnancy) delivered their babies earlier.

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<sup>7</sup> We thank an anonymous reviewer for bringing this important point to our attention.

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