The Role of Prenatal Maternal Stress in Child Development

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Abstract

The notion that a woman's psychological state during pregnancy affects the fetus is a persistent cultural belief in many parts of the world. Recent results indicate that prenatal maternal distress in rodents and nonhuman primates negatively influences long-term learning, motor development, and behavior in their offspring. The applicability of these findings to human pregnancy and child development is considered in this article. Potential mechanisms through which maternal psychological functioning may alter development of the fetal nervous system are being identified by current research, but it is premature to conclude that maternal prenatal stress has negative consequences for child development. Mild stress may be a necessary condition for optimal development.

Keywords

pregnancy; fetus; fetal development; stress

"Ay ay, for this I draw in many a tear,
And stop the rising of blood-sucking sighs,
Lest with my sighs or tears I blast or drown
King Edward's fruit, true heir to the English Crown"

—Queen Elizabeth's response upon learning of her husband's imprisonment in Shakespeare's *King Henry VI* (Part 3), Act IV, Scene IV

Since antiquity, people have thought that the emotions and experiences of a pregnant woman impinge on her developing fetus. Some of these notions, such as the idea that a severe fright marks a child with a prominent birthmark, no longer persist. However, the premise that maternal psychological distress has deleterious effects on the fetus is the focus of active scientific inquiry today. A resurgence of interest in the prenatal period as a staging period for later diseases, including psychiatric ones, has been fostered by the enormous attention devoted to the hypothesis of fetal programming advanced by D.J. Barker and his colleagues. Fetal programming implies that maternal and fetal factors that affect growth impart an indelible impression on adult organ function, including functioning of the brain and nervous system. That earlier circumstances, including those during the prenatal period, might affect later development is hardly newsworthy to developmentalists. In the 1930s, the Fels Research Institute initiated a longitudinal study of child development that commenced with intensive investigation of the fetal period.

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Possible effects of maternal psychological distress during pregnancy range along a continuum from the immediate and disastrous (e.g., miscarriage) to the more subtle and long term (e.g., developmental disorders). Most existing research has focused on the effects of maternal distress on pregnancy itself. For example, there are numerous comprehensive reviews of research indicating that women who express greater distress during pregnancy give birth somewhat earlier to somewhat lighter babies than do women who are less distressed. The focus of this report is on the potential for maternal stress to generate more far-reaching effects on behavioral and cognitive development in childhood.

MECHANISMS AND EVIDENCE FROM ANIMAL STUDIES

There are no direct neural connections between the mother and the fetus. To have impact on the fetus, maternal psychological functioning must be translated into physiological effects. Three mechanisms by which this might occur are considered most frequently: alteration in maternal behaviors (e.g., substance abuse), reduction in blood flow such that the fetus is deprived of oxygen and nutrients, and transport of stress-related neurohormones to the fetus through the placenta. Stress-related neurohormones, such as cortisol, are necessary for normal fetal maturation and the birth process. However, relatively slight variations in these hormones, particularly early in pregnancy, have the potential to generate a cascade of effects that may result in changes to the fetus's own stress response system.

The most compelling evidence of a link between maternal psychological functioning and later development in offspring is found in animal studies. Stress responses in rodents can be reliably induced by a variety of experimental methods. Deliberate exposure of pregnant laboratory animals to stressful events (e.g., restraint) produces effects on offspring. These include deficits in motor development, learning behavior, and the ability to cope effectively in stressful situations. There is a tendency for the effects to be greater in female than in male offspring. Changes in brain structure and function of prenatally stressed animals have also been documented (Welberg & Seckl, 2001). Yet not all documented effects of prenatal stress are negative; mild stress has been observed to benefit, not damage, later learning in rats (Fujioka et al., 2001).

In a series of studies, pregnant rhesus monkeys that were exposed to repeated periods of loud noise were shown to bear offspring with delayed motor development and reduced attention in infancy. A constellation of negative behaviors, including enhanced responsiveness to stress and dysfunctional social behavior with peers, persisted through adolescence (Schneider & Moore, 2000). In general, studies of stress in nonhuman primates find males to be more affected than females. However, although a study comparing offspring of pregnant pigtailed macaques that were repeatedly stressed with offspring of nonstressed mothers did find that the behavior of prenatally stressed males was less mature than the behavior of non-prenatally stressed males, for females the results were reversed. The females born to the stressed mothers displayed more mature behavior than non-prenatally stressed females (Novak & Sackett, 1996). Thus, although most studies have reported detrimental consequences, reports of either no effects or

be cial ones make it clear that much is left to be learned about the specifi characteristics of stressors that either accelerate or retard development.

DOES MATERNAL STRESS AFFECT DEVELOPMENT IN HUMANS?

Several important factors make it difficult to generalize results based on animal studies to humans. First, there are substantial physiological differences inherent to pregnancies in different species. Second, researchers are unable to control the events that transpire after birth in humans. Women who are psychologically stressed before pregnancy are also likely to be stressed after pregnancy, so it is critical that the role of social influences after birth be carefully distinguished from pregnancy effects that are transmitted biologically. Finally, the nature of the prenatal stress studied in animals and humans is very different, and this may pose the greatest barrier to the ability to generalize. In animal research, stressors are external events that are controlled in terms of duration, frequency, and intensity. The closest parallel in human studies is found in the few studies that have taken advantage of specific events, including an earthquake and the World Trade Center disaster, to study the effects on pregnancy in women residing in physical proximity. No such study has examined children's cognitive or behavioral outcomes. However, what is measured in virtually all human studies of "stress" during pregnancy is women's affect, mood, and emotional responses to daily circumstances in their lives. Maternal anxiety and, to a lesser extent, depression are prominent foci of research. Both may reflect emotional responses to stressful circumstances, but they also represent more persistent features of personality. Thus, not only are the physiological consequences and nature of prenatal stress different between animal and human studies, but when human studies detect an association between mothers' prenatal anxiety, for example, and their children's later behavior, it may be the result of shared genes or childrearing practices related to maternal temperament.

Despite these concerns, there is a small but growing literature indicating that there is a relation between pregnant women's psychological distress and their children's behavioral outcomes. In one study, the ability of 8-month-old infants to pay attention during a developmental assessment was negatively correlated with the amount of anxiety their mothers reported about their pregnancy (Huizink, Robles de Medina, Mulder, Visser, & Buitelaar, 2002). This study is one of the few in which infants' behavior was rated by an independent observer and not a parent. Two separate studies with large numbers of participants found positive associations between maternal distress (primarily anxiety) in the first half of pregnancy and behavioral disorders or negative emotionality at preschool age (Martin, Noyes, Wisenbaker, & Huttunen, 2000; O'Connor, Heron, Golding, Beveridge, & Glover, 2002). Unfortunately, both relied on mothers' reports of their children's problems, so it is impossible to know whether the results simply indicate that anxious mothers perceive their children to be more difficult than nonanxious mothers do. However, new information about potential mechanisms whereby maternal stress might affect fetal development gives plausibility to these results. Maternal anxiety is associated with reduced blood flow to the fetus (Sjostrom, Valentin, Thelin, & Marsal, 1997), and fetal levels of stress hormones reflect those of their mothers (Gitau, Cameron, Fisk, & Glover, 1998).

Remarkably, this handful of published studies represents most of what we know about the effects of maternal distress on child development. There are several additional reports in the literature, but because of problems in methods or analysis, their results are not compelling. As the field matures, methodological, analytical, and interpretational standards will emerge over time.

THE NEXT LEVEL OF INVESTIGATION

The implicit assumption has been that prenatal stress and emotions have consequences for child development after birth because they have more immediate effects on the development of the nervous system before birth. Until recently, the fetal period of development was a black box. Although fetuses remain one of the few categories of research participants who can be neither directly viewed nor heard, opportunities to measure fetal development now exist. As pregnancy advances, the behavioral capabilities of the fetus become similar to those of a newborn infant, although the fetus is limited by the constraints of the uterus. Nonetheless, measurement of fetal motor activity, heart rate, and their relation to each other provides a fairly complete portrait of fetal development. New techniques present an opportunity to examine the manner in which the psychological state of the pregnant woman may affect development prior to birth, and perhaps permanently change the offspring's course of development.

In our first efforts to examine the link between fetal behavior and maternal stress, my colleagues and I relied on commonly used paper-and-pencil questionnaires to measure maternal psychological attributes. In a small study, we found that mothers' perception of experiencing daily hassles in everyday life was inversely related to the degree to which their fetuses' movement and heart rate were in synchrony. Such synchrony is an indicator of developing neural integration (DiPietro, Hodgson, Costigan, Hilton, & Johnson, 1996). In a second study, we found that mothers' emotional intensity, perception of their lives as stressful, and, in particular, feelings that they were more hassled than uplifted by their pregnancy were positively related to the activity level of their fetuses (DiPietro, Hilton, Hawkins, Costigan, & Pressman, 2002). We had previously reported that active fetuses tend to be active 1-year-olds, so fetal associations portend postnatal ones.

Measures of maternal stress and emotions that are based on mothers' self-reports are important only to the extent that they correspond to physiological signals that can be transmitted to the fetus; thus, they provide limited information. We turned to investigating the degree to which maternal physiological arousal, as measured by heart rate and electrical conductance of the skin, a measure of emotionality, is associated with fetal behavior. The results were unexpected in that fetal motor activity, even when it was imperceptible to women, stimulated transient increases in their heart rate and skin conductance.

It became apparent to us that the only way to truly examine the effect of stress on the fetus was to subject women to a standard, noninvasive stressor

measure the fetal response. The stressor we selected was a common cognitive challenge known as the Stroop Color-Word Test. In this test, subjects are asked to read color names that are printed in various colors and so must dissociate the color of the words from their meaning. The test is not aversive but reliably induces physiological arousal. In general, when pregnant women engaged in this task, fetal motor activity was suppressed, although individual responses varied. The degree to which individual women and fetuses responded to the Stroop test was similar from the middle to the end of pregnancy. These results lead us to propose three hypotheses. First, women respond to stress in characteristic ways that fetuses are repeatedly exposed to over the course of pregnancy. This experience serves to sensitize the developing nervous system. Second, there are both short-term and longer-term adaptive responses to stress by the fetus, depending on the intensity and repetitiveness of the stimulation. Finally, the immediacy of the fetal response to the Stroop, as well as to maternal viewing of graphic scenes from a movie on labor and delivery, suggest an additional mechanism whereby maternal stress might affect the fetus. We propose that the fetus responds to changes in the sensory environment of the uterus that occur when maternal heart rate, blood pressure, and other internal functions are abruptly altered. This proposal cannot be readily tested, but hearing is among the first perceptual systems to develop prenatally, and it is well documented that the fetus can perceive sounds that emanate from both within and outside the uterus.

Our final foray into this area of inquiry has been to follow children who participated in our studies as fetuses. Recently, we completed developmental testing on approximately one hundred 2-year-old children. The results, as is often the case in fetal research, surprised us. Higher maternal anxiety midway through pregnancy was strongly associated with better motor and mental development scores on the Bayley Scales of Infant Development, a standard developmental assessment. These associations remained even after controlling statistically for other possible contributing factors, including level of maternal education and both anxiety and stress after giving birth. This finding is in the direction opposite to that which would be predicted on the basis of most, but not all, of the animal research. Yet it is consistent with what is known about the class of neurohormones known as glucocorticoids, which are produced during the stress response and also play a role in the maturation of body organs. Our results are also consistent with findings from a series of studies on physical stress. The newborns of pregnant women who exercised regularly were somewhat smaller than the newborns of women who did not exercise much, but showed better ability to remain alert and track stimuli; the children of the regular exercisers also had higher cognitive ability at age 5 (Clapp, 1996). Exercise and psychological distress do not necessarily have the same physiological consequences to the fetus, but the parallel is intriguing.

CONCLUSIONS

At this time, there is too little scientific evidence to establish that a woman's psychological state during pregnancy affects her child's developmental outcomes. It is premature to extend findings from animal studies to women and children, particularly given the disparity in the way the animal and human studies are designed. The question of whether maternal stress and affect serve to accelerate or inhibit maturation of the fetal nervous system, and postnatal development in turn, remains open. It has been proposed that a certain degree of stress during early childhood is required for optimal organization of the brain, because stress provokes periods of disruption to existing structures (Huether, 1998), and this may be true for the prenatal period as well.

The relation between maternal stress and children's development may ultimately be found to mirror the relation between arousal and performance, which is characterized by an inverted U-shaped curve. This function, often called the Yerkes-Dodson law, posits that both low and high levels of arousal are associated with performance decrements, whereas a moderate level is associated with enhanced performance. This model has been applied to a spectrum of psychological observations, and a parallel with prenatal maternal stress may exist as well. In other words, too much or too little stress may impede development, but a moderate level may be formative or optimal. The current intensive investigation in this research area should provide better understanding of the importance of the prenatal period for postnatal life as investigators direct their efforts toward determining how maternal psychological signals are received by the fetus.

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Critical Thinking Questions

1. What leads the author to believe that maternal stress can cause development changes in a fetus?
2. Summarize the findings from animal studies on the role of prenatal maternal stress.
3. Describe the challenges and approaches for conducting research on prenatal stress in humans.
4. What does the author conclude about the state of the science when it comes to the role of prenatal maternal stress in humans?

Infants' Physical World

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Abstract

Investigations of infants' physical world over the past 20 years have revealed two main findings. First, even very young infants possess expectations about physical events. Second, these expectations undergo significant developments during the first year of life, as infants form event categories, such as occlusion, containment, and covering events, and identify the variables relevant for predicting outcomes in each category. A new account of infants' physical reasoning integrates these findings. Predictions from the account are examined in change-blindness and teaching experiments.

Keywords

infant cognition; physical reasoning; explanation-based learning

Over the past 20 years, my collaborators and I have been studying how infants use their developing physical knowledge to predict and interpret the outcomes of events. This article focuses on infants' knowledge about three event categories: occlusion events, which are events in which an object is placed or moves behind a nearer object, or occluder; containment events, which are events in which an object is placed inside a container; and covering events, which are events in which a rigid cover is lowered over an object (Baillargeon & Wang, 2002). I first summarize two relevant bodies of developmental findings, and then point out discrepancies between these findings. Next, I outline a new account of infants' physical reasoning that attempts to make sense of these discrepancies. Finally, I describe new lines of research that test predictions from this account.

All of the research reviewed here used the violation-of-expectation method. In a typical experiment, infants see an expected event, which is consistent with the expectation examined in the experiment, and an unexpected event, which violates this expectation. With appropriate controls, evidence that infants look reliably longer at the unexpected than at the expected event indicates that they possess the expectation under investigation, detect the violation in the unexpected event, and respond to this violation with increased attention.

PRIOR FINDINGS

Beginnings

Infants as young as 2.5 months of age (the youngest tested to date) can detect some violations in occlusion, containment, and covering events (see Fig. 1). For

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