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A

THE EFFECT OF MATERNAL EMOTION ON FETAL BEHAVIOR

by

YVONNE R. MASAKOWSKI

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

1996

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## Approval Page

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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**Abstract****THE EFFECT OF MATERNAL EMOTION ON FETAL BEHAVIOR**

by

**Yvonne R. Masakowski****Adviser: Professor Gerald Turkewitz**

The purpose of this study was to examine the effects of maternal emotion on fetal behavior. 32 nulliparous pregnant women (36-40 weeks gestation) were presented with three 30s film segments depicting breastfeeding, nature and labor scenes. Film segments were presented during the first period of low fetal heart rate variability, the fetal analog of quiet sleep. Maternal heart rate, blood pressure and respiration were recorded, as well as fetal heart rate, body movements and breathing movements.

The breastfeeding film segment elicited a significant decrease in maternal blood pressure (-3.4 mm Hg,  $p < 0.05$ ) and a significant increase in maternal respiration rate (3.2,  $p < 0.01$ ). Concomitant with maternal physiological changes, there was a marginally significant increase in fetal heart rate (1.14 bpm,  $p < 0.05$ ) and a significant increase in fetal breathing movements, (3.5 breaths/minute,  $p < 0.01$ ), during the second 10s of the breastfeeding film. Fetal heart rates increased in association with an increase in maternal respiration rate, a decrease in breath amplitude and a decrease in blood pressure. Physiological changes associated with maternal emotions exert an influence on fetal behavior which may have consequences for neonatal development.

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This dissertation is dedicated to my husband, Daniel and my children Jennifer and Daniel. I especially want to acknowledge my mother, Cecilia A. Centak for her encouragement and for teaching me the merits of setting standards of excellence and the rewards of perseverance. My family's love, patience, encouragement and support made the pursuit of my personal and professional goals possible.

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## **INTRODUCTION**

The emotional state of the pregnant woman has been the focus of numerous studies (Benson, Little, Talbert, Dewhurst & Priest, 1987; Farber, Vaughn & Egeland, 1981; Ferreira, 1965; Frank, Tuber, Slade & Garrod, 1994; Ianniruberto & Tajani, 1981; Lederman, Lederman, Work & McCann, 1978, 1985; Montenegro, Palomino & Palomino, 1995; Piontelli, 1992; Rofe, Blittner & Lewin, 1993; Sontag, 1941; Talbert, Benson & Dewhurst, 1982; Thompson, Watson & Charlesworth, 1962; Van den Bergh, Mulder, Visser, Poelmann-Weesjes, Bekedam & Precht1, 1989; Van den Bergh, 1992; Zuckerman, Bauchner, Parker & Cabral, 1990). The majority of these studies have shown that the emotional state of the pregnant woman plays a significant role in fetal development. To date, relatively little is known about the effect of acute changes in maternal emotion on fetal behavior. Therefore, the aim of this study is to examine the effects of acute changes in maternal emotion on fetal behavior.

The human fetus is subject to the influence of environmental factors that may facilitate, perturb or impede the normal course of ontogeny. The literature concerning the relationship between prenatal exposure to substances such as alcohol, cocaine and reproductive outcome is extensive (Barton, Harrigan & Tse, 1995; Bonthius & West, 1991; Gingras, Feibel, Dalley, Muelenaer & Knight, 1995; Hepper, 1995; Hurt, Brodsky, Braitman, Malmud & Giannetta, 1995;

Kain, Rimar & Barash, 1993; Rosett, Snyder, & Sander, 1979; Walpole, Zubrick & Pontre, 1991). Prenatal exposure to substances such as cocaine has been shown to negatively impact the organization of behavioral sleep states (Gingras et al., 1995; Hepper, 1995). Specifically, cocaine-exposed fetuses exhibited prolonged periods of inactivity in association with an increase in the number of startles during sleep (Hepper, 1995). While these studies show the detrimental consequences of prenatal exposure to teratogenic substances, there are other, more subtle environmental sources of stimulation which may affect fetal behavior and neonatal outcome.

Specifically, prenatal exposure to severe emotional stress has been shown to have a negative effect on fetal development and neonatal outcome (Ferreira, 1965; Ianniruberto & Tajani, 1981, Montenegro et al., 1995). Although there appears to be no single link between anxiety and the development of morphological anomalies, there is evidence that prenatal stress exposure may disrupt normal fetal behavior and affect neonatal outcome. Prenatal factors have been linked to the development of affective disorders (Brown, Susser, Lin, Neugebauer & Gorman, 1995). Brown et al., (1995) showed that second trimester fetuses who were exposed to famine during the Dutch hunger winter of 1944-1945 were at greater risk for the development of affective disorders later in life. In addition, pregnant

women who had been in an earthquake in southern Italy had fetuses who exhibited sustained hyperactivity for a period of eight hours (Ianniruberto & Tajani, 1981). In another incident, pregnant women who had been in an earthquake had a greater than normal incidence of infants born with cleft palate (Montenegro et al., 1995). Investigators attributed this defect to the effects of stress induced in pregnant women during the earthquake. These results suggest a relationship between prenatal emotional experience and neonatal outcome. Given the evidence for the influence of prenatal stress on fetal development, one might posit that repeated exposure to prenatal stress and anxiety may have a cumulative effect on the fetus.

The relationship between maternal anxiety and reproductive outcome has become one of the most frequently studied issues in obstetric research since maternal anxiety has a direct effect on both maternal and fetal physiology (Ascher, 1978; Bekedam, Mulder, Snijders & Visser, 1991; Crandon, 1979; Lederman et al., 1985; Van den Bergh et al., 1989). For example, a positive correlation between maternal state anxiety and fetal activity has been reported (Van den Bergh et al., 1989). Anxious pregnant women also tend to experience a greater incidence of premature labor, stillbirths and miscarriages (Aldrich, D'Antona, Spencer, Wyatt, Peebles, Delpy & Reynolds, 1995; Reece, Hobbins, Mahoney & Petrie, 1995). In addition, anxious pregnant

women experience longer durations of labor. During prolonged labor, there is an increase in vasoconstriction of the uterine artery which restricts blood flow and oxygen to the placenta and fetus (Lederman et al., 1985). A reduction in uterine blood flow to the placenta will evoke a decrease in fetal heart rate and fetal asphyxia (Friedman & Kirkpatrick, 1977). Conversely, when mothers of intrauterine growth-retarded fetuses (IUGR) were hyper-oxygenated, their fetuses exhibited an increase in fetal heart rate, breathing and body movements (Bartnicki & Saling, 1994; Bekedam et al., 1991). These studies demonstrate the essential role that maternal oxygenation plays in fetal growth and development.

The psychological state of the pregnant woman also contributes to fetal behavior and neonatal outcome (Farber, Vaughn & Egeland, 1981; Piontelli, 1988, 1992; Snidman, Kagan, Riordan & Shannon, 1995). Maternal expectations of infant temperament have been associated with the pregnant woman's physical and psychological experiences during her pregnancy (Chazan & Carter, 1996). Those women who had positive feelings toward their fetus and experienced a healthy pregnancy were more likely to feel positively toward their infant. Maternal depression also has been shown to influence development such that, during the first year of life, infants of depressed women were more likely to exhibit developmental delays (Lundy, Field & Pickens, 1996). In another study, one-month old infants of depressed mothers

were found to have asymmetries in right frontal EEG activity (Jones, Field, Lundy & Davalos, 1996). Measures of EEG activity have been used to examine the expression of different emotions such that right frontal activity has been related to epochs of sadness, while left frontal activity has been associated with happiness (Dawson, 1994). In combination, these findings suggest that the psychological state of the pregnant woman may have important consequences for fetal frontal lobe development. There is evidence that depressed patients have higher cortisol levels than normal. Therefore, the fetal central nervous system of a depressed pregnant woman would develop in the presence of higher cortisol levels than that of a non-depressed pregnant woman. One might theorize that the development of the right frontal asymmetries observed in one-month old infants may be related to physiological changes related to depression that occurred during the course of pregnancy.

Furthermore, the psychological and emotional state of the mother may facilitate the development of healthy, secure attachment. The quality of attachment has been associated with the mother's ability to provide external regulation for her child, as well as the mother's emotional availability for the development of mother/infant interactions (Easterbrooks, Lyons-Ruth, Biesecker & Carper, 1996). Recent evidence has shown that the development of a secure attachment may depend upon the integration of the mother's

positive emotions toward her fetus during pregnancy (Frank, et al., 1994). The level of attachment appeared to increase over the course of gestation. Pregnant women who had positive perceptions of their baby prenatally, were more inclined to continue feeling positively postnatally. However, these findings ought to be considered within the context of pregnancy because physiological responses associated with positive emotions are subject to the influence of cognitive interpretation (Schachter & Singer, 1962). Thus, pregnant women who feels positively about the pregnancy is more likely to interpret physiological responses during pregnancy positively. Therefore, the relationship between maternal emotions and fetal behavior is subject to the influence of the pregnant woman's feelings toward the pregnancy itself.

The fetus is also responsive to less intense maternal emotional stimulation. While mothers listened to their preferred music, there was a significant increase in fetal body movements and a significant decrease in fetal breathing movements (Zimmer, Divon, Vilensky, Sarna, Peretz & Paldi, 1982). Fetuses exhibited an increase in heart rate as their mothers listened to the recorded sounds of infant crying (Talbert et al., 1982), the magnitude of which increased in relation to the level of maternal anxiety (Benson et al., 1987).

These studies demonstrate that the fetus has extended

experience with different patterns of maternal physiological responses associated with maternal emotional state. However, while these studies show that there may be a connection between maternal psychological and emotional state during pregnancy and behavioral development, none have explored the effects of multiple sources of maternal physiological changes associated with emotion on fetal behavior. Each of the above studies contributes important information regarding the ways in which maternal emotions can exert an influence on fetal behavior and neonatal outcome. Repeated exposure to brief episodes of maternal emotion during pregnancy may modify the relationship between maternal physiology and fetal behavior.

Extended experience with maternal physiological changes associated with emotion may trigger changes in fetal behavior which facilitate the development of skills necessary for the neonate to adapt to its new environment. The fetus' ability to detect, discriminate and respond to modulations in maternal physiology may not only be necessary for maintaining homeostasis, but also may influence the development of more complex patterns of fetal behavior.

Maternal and fetal behavioral interactions may provide experience with sensory information that will have long lasting effects. For example, pregnant baboons that were stressed by exposure to bright lights exhibited a decrease in uterine blood flow which elicited a decrease in fetal

heart rate and oxygenation (Morishima, Yeh & James, 1979). When maternal agitation was discontinued, fetal heart rate returned to normal. Fetal bradycardia has been interpreted as a compensatory response to a decrease in utero-placental blood flow and oxygen as evidenced by pregnant rhesus monkeys' response to a stressful event (Myers, 1975, 1977, 1979). Perhaps, prenatal experience with maternal anxiety associated with a stressful event may provide important experience such that the fetus develops compensatory strategies that make it better equipped to respond adaptively to changes in the environment. Therefore, the fetus' response to maternal physiological changes, regardless of whether the fetus is animal or human, may foreshadow the development of the behavioral repertoire of the neonate.

The fetus experiences changes in stimulation as a consequence of an evolving environment. During pregnancy, the uterus is transformed from the small, flaccid compartment of early gestation to the large, thin and taut compartment of the third trimester (Turkewitz, 1988, 1989). This change in the physical size of the uterus occurs in association with fetal development and a decrease in the volume of amniotic fluid. These physical modifications alter both the fetal environment and sensory experience. Fetal behavior is shaped by sounds, vibrations and tactile stimuli which may be either buffered or enhanced depending

upon the level of amniotic fluid within the environment.

There is extensive evidence in the literature regarding the fetus' capacity to respond to a variety of sensory stimuli (Lecanuet, Granier-Deferre & Busnel, 1989; Querleau, Renard, Versyp, Paris-Delrue & Crepin, 1988; Querleau, Renard, Boutteville & Crepin, 1989). The fetus responds selectively to sounds as a function of their acoustic characteristics (Kisilevsky, Muir & Low, 1989; Lecanuet et al., 1989). This evidence suggests that the fetus forms associations between the various characteristics of sound, including the intensity, frequency and duration of specific sounds. The near-term fetus exhibits differential heart rate responses according to the acoustic characteristics of the stimulus (Lecanuet, Granier-Deferre & Busnel, 1989). Fetal responsivity to acoustic stimulation has been shown to vary according to the intensity of the stimulus. High intensity acoustic stimuli (>105 dB) elicit a fetal heart rate acceleration and startle response which has been associated with a defensive response. Less intense acoustic stimuli (<100 dB) elicit a fetal heart rate deceleration which has been interpreted as an orienting response (Lecanuet et al., 1989). These studies demonstrate that the fetus has the ability to discriminate and respond differentially to auditory stimuli.

Fetal reactivity to auditory stimuli has been demonstrated in studies using vibro-acoustic stimuli

(Gagnon, Hunse, Carmichael, Fellows & Patrick, 1986; Kisilevsky & Muir, 1991, 1993; Kisilevsky, Muir & Low, 1989, 1990; Leader, Baille, Martin & Vermeulen, 1982; Leader & Baille, 1988; Leader, Stevens & Lumbers, 1988; Lecanuet, Granier-Deffere & Jacquet, 1992; Masakowski, Dietz, Carmichael, LaRosa, Brazleton & Lester, 1996; Visser, Mulder, Wit & Prechtl, 1989; Zimmer, Chao, Guy, Marks & Fifer, 1993) and noise (Lecanuet et al., 1989). For example, the fetal heart rate response was used to examine the fetus' ability to habituate (Lecanuet et al., 1989). Fetuses were presented with two syllable pairs during a period of low fetal heart rate. Fetuses exhibited a decelerative heart rate response when the order of syllable presentation was reversed. This differential response pattern of fetal reactivity has been interpreted as an indication that the fetus perceived a shift in the acoustic structure of the stimulus. Furthermore, fetal reactivity to vibroacoustic stimulation has been used as a marker for developmental delay such that longer latencies have been found in high risk fetuses (Kisilevsky et al., 1990).

Fetal cardiac reactivity has been interpreted as the primary measure of attention and arousal similar to that found in infants (Berg, 1974; Berg & Berg, 1987). Fetal reactivity has been investigated using the cardio-respiratory response of the fetus as a measure of attention and arousal (DeCasper, Lecanuet, Busnel, Granier-Defferre &

Maugeais, 1994; Fifer & Moon, 1989). A deceleration in heart rate has been interpreted as an orienting response, while an increase in heart rate indicates a defensive response similar to that of infants (Clarkson & Berg, 1983). The majority of evidence that the fetus perceives changes in its environment is based upon studies of fetal cardiac reactivity to auditory stimuli (Lecanuet et al., 1989; Fifer & Moon, 1995). For example, Lecanuet et al. (1989) showed that low intensity sounds elicit a decelerative heart rate response in the term fetus.

Studies have shown that the fetus can respond to speech sounds (Fifer, Masakowski, Tunick & Zimmer, 1993; Fifer & Moon, 1994, 1995; Hepper, Scott & Shahidullah, 1993). The amniotic compartment is the first environment in which the fetus experiences the acoustic and prosodic properties associated with speech, wherein the development of linguistic preferences are shaped (Moon, Cooper & Fifer, 1990).

Near-term fetuses, presented with repeated presentations of a nursery rhyme from 33-37 weeks gestation, exhibited a cardiac orienting response to the familiar target nursery rhyme whereas the control rhyme did not elicit such a response (DeCasper et al., 1994). Fetal cardiac reactivity serves as a measure of the fetus' ability to discriminate between novel and familiar stimuli. Fetal exposure to specific patterns of speech sounds, such as

those found in the maternal nursery rhyme, suggests that late gestation fetuses become perceptually attuned to the distinct prosodic properties encoded in the maternal nursery rhymes.

Prenatal experience with maternal voice provides a rich source of sensory stimulation for the fetus. Fetal sensitivity to the acoustic properties of maternal speech suggests that the fetus also may be sensitive to other sources of stimulation such as, maternal heart beat sounds and maternal physiological changes. Indeed, maternal heart beat sounds have been shown to be a salient reinforcer for neonates which has been interpreted as the result of prenatal experience with maternal heart beat sound (DeCasper & Sigafos, 1983).

Fetuses also have shown differential responses during periods in which mothers either spoke or whispered (Masakowski & Fifer, 1994). The results revealed that fetuses showed a decelerative heart rate response to naturally occurring maternal speech and some of the fetuses may have had a marginally significant change in heart rate during maternal whispering epochs. These results indicate that the fetus experienced both the sound of its mother's voice and those physiological changes (e.g. maternal respiratory muscle movements and diaphragmatic muscle movements) that occur coincident with whispering. When pregnant women speak or whisper, there are physiological

changes such as an increase in the frequency of respiratory muscle movements and the compression of the diaphragm which provide the fetus with tactile and vestibular stimulation. The fetus has been shown to have the ability to attend to the specific syllabic structure and repetitious, rhythmic beats incorporated in the grammatical structure of a nursery rhyme (DeCasper et al., 1994). In addition, the fetus' perception of rhythmic patterns, such as maternal heart beat sounds and maternal respiratory muscle movements coincident with speech production, suggests that the fetus might be equally attentive to repetitious, maternal physiological response patterns associated with emotion (Masakowski & Fifer, 1995).

Throughout gestation, the fetus repeatedly experiences maternal physiological response patterns associated with joy, sadness, anger and anxiety. Each of these emotions occurs in association with a variety of physiological changes such as an increase in heart rate (joy) or a decrease in heart rate (sadness) (Sinha, Lovallo & Parsons, 1992). If the fetus has the capacity to attend to acoustic and prosodic patterns associated with maternal speech, then the fetus may similarly be responsive to patterns of maternal physiological responses associated with emotion.

Fetal reactivity has been related to newborn behavior (Piontelli, 1987, 1988, 1989, 1992). The amount (active vs inactive) and quality (smooth vs jerky) of fetal body

movements have been used as markers of temperament seen in newborns (Piontelli, 1989, 1992). Pregnant women form images of their infant's temperament based upon the level of activity throughout gestation such that attributions of fetal behavior are continued throughout the postnatal period (Piontelli, 1989, 1992).

In another study, fetal cardiac activity was interpreted as an index of temperamental qualities (Snidman et al., 1995). In that study, longitudinal cardiac data was collected from the last trimester of pregnancy through 21 months of age. Fetal heart rate during the last trimester was found to be a sensitive predictor of infant temperament. Other studies have shown that the fetal heart rate of an anxious pregnant woman is higher than that of a non-anxious pregnant woman (Benson et al., 1987; Talbert et al., 1982). This may represent a defensive response to maternal physiological changes associated with an increase in anxiety levels. Talbert et al.'s study (1982) also showed that anxious pregnant women had a higher baseline heart rate than that of non-anxious pregnant women. If the cardiovascular system of an anxious pregnant woman is different than that of a non-anxious pregnant woman, then this finding suggests that these fetuses develop within environments which are physiologically different. These fetal responses may, in fact, help influence later patterns found in the mother/infant interaction during the newborn period. For

example, the fetus of an anxious mother experiences a distinct pattern of maternal physiological responses (e.g. elevated maternal heart rate, blood pressure and faster breathing rates) as compared with that of a non-anxious woman.

Until now, studies have focused on the influence of maternal emotions on the fetus by examining one of several maternal physiological factors (e.g. heart rate) on fetal behavior. Maternal emotions fluctuate throughout the course of daily living, thereby providing the fetus with a variety of sensory experiences including an increase in maternal heart beat sounds, an increase in maternal respiratory muscle movements and a decrease in utero-placental blood flow to name but a few. The mechanism(s) by which maternal emotions are transduced to the fetus remains unclear. Although there are numerous physiological measures that may play a role in conveying maternal emotions to the fetus (e.g. maternal cortisol, catecholamines), this study will address this issue by exploring the relationship between the maternal physiological changes (i.e. heart rate, blood pressure and respiration) and fetal behavior.

One of the problems in studying the influence of emotion has been the reliable elicitation of the appropriate emotional state. Film-viewing has provided one successful means of approaching this problem as evidenced in previous studies (Hubert & de Jong-Meyer, 1990, 1991; Lazarus,

Speisman, Mordkoff & Davison, 1962; Van den Bergh et al., 1989). For example, Hubert & de Jong-Meyer (1990) presented positive, neutral and negative films to induce cardiovascular and respiratory changes in adults. Scenes from the animated cartoon *Peanuts* served as a positive film stimulus and a scene from the suspense movie *Indiana Jones - Raiders of the Lost Ark* served as a negative film stimulus. During the negative film, subjects reported feelings of anxiety in association with an increase in heart rate and respiration. During the positive film, subjects reported a sense of relaxation in association with a stable heart rate and respiration rate.

Responses to emotionally laden films also have been used as a means of evaluating the effects of maternal emotions on fetal behavior (Van den Bergh et al., 1989). A 26 min. labor film was presented to anxious and non-anxious pregnant women in order to assess the effects on fetal behavior. Maternal anxiety was positively correlated with the amount of fetal motor activity. This study demonstrated that emotions could be induced by showing a film of a normal delivery to pregnant women. However, this study did not show a link between maternal physiological changes and fetal heart rate. One might speculate that fetal physiological changes may have been influenced by changes in maternal catecholamine levels. Studies have shown that an increase in maternal anxiety has been associated with an increase in

maternal catecholamines (Lederman et al., 1985; Myers, 1975, 1977). In addition, an increase in maternal anxiety restricts uterine blood flow due to the vasoconstrictive properties of catecholamines. While there are several pathways by which maternal emotional changes might have been transduced to the fetus, the only maternal physiological variable monitored during this study was heart rate. The fetus is also exposed to the composite of maternal physiological changes associated with emotion such as heart rate, blood pressure and respiratory changes which may have contributed to the fetal response in this study. Therefore, these maternal physiological changes should be examined in order to more fully understand the relationship between maternal emotions and fetal behavior.

In summary, the fetus is differentially responsive to specific patterns of sounds including maternal speech, nursery rhymes and maternal heart beat. Prenatal exposure to specific patterns of acoustic information and physiological events that occur concomitant with maternal speech and maternal heart beat sounds have been shown to influence the development of neonatal preferences. Acute changes in maternal emotion are often transient, however, sudden changes in maternal heart rate, blood pressure and respiration may initiate a fetal response. One might posit that the physiological system of the fetus may be buffered from sudden changes in maternal physiology. Alternatively,

the fetus may continuously be required to make a defensive response to an increase in maternal heart rate, blood pressure and respiration. While there is individual variation in response to discrete emotional events, physiological changes associated with maternal emotion may regulate the fetal physiological system (i.e. fetal heart rate, breathing and body movements) and provide sensory experience that may be essential for normal behavioral development.

This study will attempt to expand our knowledge of fetal experience with maternal emotion. Prenatal experience with maternal physiological changes associated with emotion may facilitate the development of the fetus' ability to discriminate sensory information. For example, an increase in maternal heart rate and respiration rate is associated with auditory, mechanical and physiological events. Fetal experience with maternal emotion may provide sensory experience that may forge the development of behavioral response patterns which may influence the neonatal development of temperament, attachment and language. The question is, will fetuses respond to acute changes in maternal emotions?

## **Method**

### **Subjects**

Forty pregnant, nulliparous women (aged 15-40 years) in their 36-40th week of pregnancy were recruited from the Perinatal Clinic at Columbia-Presbyterian Medical Center under guidelines set by the Institutional Review Board of Columbia Presbyterian Medical Center (Appendix III). Only pregnant women with singleton pregnancies were invited to participate. Exclusion criteria included any history of medical complications, such as gestational diabetes, hypertension, pulmonary, cardiovascular or neurological abnormalities, as well as any prescribed or other drug use, including nicotine. Subjects had not previously viewed films depicting labor, delivery or breastfeeding. Of the 40 women recruited, three subject pairs (mothers & fetuses) were eliminated from this study because of maternal hypertension. In addition, three subject pairs were unable to complete the study because their fetuses never reached the quiet state during the study session. One subject pair was deleted from the study because of excessive fetal heart rate artifact.

Gestational age was estimated at the time of the study using the date of the last menstrual period (LMP). The estimated gestational age during the study was 36-40 weeks, with a mean gestational age of 37.3 weeks. The mean gestational age at birth was 39.6, with ages ranging from 36-42 weeks. In this sample, infants were delivered

vaginally and were normal with Apgar scores of 7 or higher at 5 and 10 minutes (Appendix IV). Only one infant was classified as low birth weight (<2400 gms). Data from this subject was not included in the analysis. (N=32)

### **Apparatus**

#### **Maternal heart rate & blood pressure recording.** A

Hewlett Packard Model 78302A was employed to monitor maternal cardiac and respiratory activity. A Cor 7000 Medical Systems blood pressure monitor (model C121303) recorded beat-to-beat maternal blood pressure using a continuously inflated cuff.

Throughout the study, maternal heart rate, blood pressure and respiration were continuously recorded. Electrodes were placed on the subject's chest to record both heart rate and respiration. A continuously inflated blood pressure cuff was placed on the subject's arm to monitor beat-to-beat changes in maternal blood pressure.

#### **Fetal heart rate, breathing & movement recording.** A

Toshiba SSA-140A Ultrasound system with color flow and spectral Doppler analysis capabilities was used to monitor and record fetal behaviors. Transducer frequency was set at 3.75 MHz. An Advanced Medical Systems (model IM76) transducer was placed on the maternal abdomen to monitor fetal heart rate and body movements. Fetal breathing

movements were recorded by scanning the fetal nose with the ultrasound transducer (Badalian, Chao, Fox & Timor-Tritsch, 1993; Badalian, Fifer, Fox, Masakowski, Myers & Leung, 1995). The transducer was placed on the maternal abdomen above the fetus' nose to optimize a sagittal view of the nasal fluid flow. Inspiration and expiration data were collected using pulsed Doppler ultrasound. The acoustic signal of these breathing movements was recorded on one of two channels of an FM stereo recorder and digitized for future analysis.

Fetal body movements (i.e. smooth, jerky, gross) were monitored solely for the purpose of detecting movement since fetal body movements are often coincident with an increase in fetal heart rate. Stimuli were presented only during fetal state 1F which is a period of quiescence analogous to the quiet sleep state of the neonate. The average quiet/active cycle of the fetus is one quiet period during a 90 minute session (Nijhuis, 1992). Sleep state 1F is characterized by periods of low fetal heart rate variability during which fetal heart rate could not exceed a change of >5 bpm from baseline to the stimulus (Nijhuis, Prechtl, Martin & Bots, 1982, Nijhuis & van de Pas, 1992). A period of 3 minutes of low fetal heart rate variability was required prior to maternal stimulation. If the fetus became active or its heart rate exceeded this criterion, stimulus presentation was delayed until the fetal heart rate returned

to baseline.

### **Stimuli**

Three 30s film segments were classified during a pilot study in which both pregnant and non-pregnant subjects reported their affective responses to each film. Women rated films on a continuum of positive to negative affective responses. The positive film depicted a mother smiling as she was being instructed in breastfeeding her infant. The neutral film consisted of a nature scene which was accompanied by melodic music. The negative film depicted a woman during the birthing process whose behavior and vocalizations were suggestive of pain associated with labor and delivery.

The three films were presented to each woman in either of two orders, with a 90s inter-film interval. The breastfeeding (positive) and labor (negative) films alternated between being either the first or the third film presented. The nature stimulus (neutral) was always presented as the second stimulus to reduce any undue emotional influence from the preceding film.

### **Procedure**

Subjects were tested in a quiet room in the Ultrasound Department of the Columbia-Presbyterian Medical Center. Subjects signed an informed consent form in compliance with

the guidelines of Columbia-Presbyterian Medical Center (Appendix V). Subjects completed a self-report anxiety questionnaire (Spielberger, Vagg & Barker, 1980) at the beginning of each session. The Spielberger State-Trait Anxiety Inventory (STAI) questionnaire is the most common instrument used to distinguish between state and trait anxiety levels. Subjects responded to twenty items on a four point scale (Appendix VI).

Following completion of the State/Trait anxiety questionnaire, subjects reclined in a semi-recumbent position on a hospital bed. Headsets were used to present the auditory portion of the film segments to each pregnant woman. Subjects viewed the three 30s film segments which were presented on a television monitor placed at the foot of the bed.

Electrodes were placed on the maternal chest to monitor maternal heart rate. A blood pressure cuff was placed over the maternal brachial artery which would remain continuously inflated throughout the study. A transducer was placed on the maternal abdomen to monitor fetal heart rate and body movements. Fetal breathing movements were monitored using a Doppler ultrasound transducer placed on the maternal abdomen above the fetal nose.

Maternal and fetal behavior were monitored for a minimum baseline period of 10 minutes prior to the presentation of the first film. Following the baseline

period, a period of low fetal heart rate variability was established prior to proceeding with the study. One of the principal defining parameters of fetal sleep state 1F is heart rate that must remain stable for a minimum of three minutes (Nijhuis, 1992). The incidence of fetal sleep states is variable and a fetus may remain in a quiet sleep state for approximately 20 minutes (Nijhuis, 1992). The minimum duration of each study session was 90 minutes to ensure at least one episode of fetal quiet state. Due to the relatively brief duration of fetal state 1F, i.e. 15-20 minutes, three 30s film segments with 90s inter-trial-intervals were used.

Maternal heart rate, blood pressure, respiration rate and fetal heart rate data were collected throughout the session. Fetal body movements were monitored for the sole purpose of controlling for stimuli presentation such that, during each trial, stimulus presentation was prohibited by an increase in fetal body movements. Likewise, stimuli were not presented during periods in which fetal heart rate exceeded 5 bpm from baseline to the stimulus. Subjects whose fetuses did not achieve quiet sleep state were invited to return to the study if no stimuli had been presented.

Once the study was completed, subjects completed a reaction questionnaire which was designed to record their reactions to each film segment (Appendix VII).

### **Data Reduction and Analyses**

Data from 32 subjects were analyzed. Data were divided into four 10s epochs, a 10s baseline and three 10s stimulus epochs. Maternal physiological dependent variables (heart rate, blood pressure, breath-to-breath intervals and breath amplitude) and fetal dependent variables (heart rate and breath-to-breath intervals) were analyzed. Prior to analyses, data were examined to identify and remove artifacts which were related to equipment error. For example, maternal blood pressure data, which exceeded a 20 mm Hg change from one epoch to the next, was designated as artifact and deleted prior to analysis.

Peaks and troughs in the maternal respiration wave form were marked by a special software package. The amplitude of breaths, marked by a change from peak to trough, could not be collected for every epoch due to excessive artifact as a consequence of maternal body movement.

Fetal breathing movements were similarly analyzed using a software package. A criterion was set which required three consecutive breaths within a 10s period prior to continuing with analysis. Fetal breathing is episodic and therefore there were only a few number of fetuses whose breathing movements were continuously recorded during both the baseline and stimulus epochs. Thus, the analyses were conducted for only those fetuses whose breathing movements were recorded during both baseline and stimulus epochs.

### **Data Analyses**

Descriptive statistics, repeated measures ANOVAs, paired- $t$  tests and multiple-regression analyses were conducted using a PC version of the SYSTAT (version 5.03). SYSTAT software is a comprehensive software package which affords the flexibility to perform all of the required analyses employed in this study.

For each dependent variable (maternal and fetal physiological variables), a repeated measures ANOVA was run to compare responses across four epochs: the 10s baseline epoch (i.e. the 10s prior to the stimulus) and the three 10s stimulus epochs (i.e. the 30s stimulus period divided into three 10s epochs). Repeated measures ANOVA have been shown to control for within subject variability (Keppel, 1982). When the repeated measures ANOVA  $F$  was significant or approached significance ( $p < 0.10$ ), paired- $t$  analyses were conducted to compare the baseline with each stimulus period. The Bonferroni correction was used to control experimentwise Type I error, adjusting the initial two-tailed alpha level  $p < 0.05$  to  $p < 0.017$ . Marginally significant results are also reported. Lastly, multiple-regression analyses were conducted as a means of predicting fetal heart rate changes from a combination of maternal physiological variables. The multiple-regression analyses was conducted as a means of providing a model of the relationship between maternal

physiology and fetal heart rate. Descriptive statistics were computed for the Spielberger State and Trait Anxiety Assessment scores and the video reaction scores.  $t$  tests were also conducted to compare fetal heart rate responses between anxious and non-anxious mothers.

#### **MATERNAL AND FETAL PHYSIOLOGICAL VARIABLES**

Maternal Heart Rate	MHR (bpm)
Maternal Blood Pressure	MBP (mm Hg)
Maternal Breath-to-Breath Interval	MBBI (ms)
Maternal Breath Amplitude	MAMP
Fetal Heart Rate	FHR (bpm)
Fetal Breath-to-Breath Interval	FBBI (ms)

## **Results - Data Reduction and Analyses**

### **Baseline Data and the Effects of Order**

A summary of baseline maternal state and trait anxiety scores is provided in Table 1. A mean score on the Spielberger assessment scale of 50 or greater indicates an anxious state and/or trait. In this study, the average State anxiety score was 37.3 (N=32, SD=9.4) and the average Trait anxiety score was 37.4 (N=32, SD=11.2). These means fall within the range of the normal population and do not indicate atypical responses at the time mothers described themselves.

Table 2 presents descriptive statistics for baseline values prior to each film presentation for each maternal and fetal dependent variable. There were no significant differences among the baselines obtained prior to viewing the three different films for any of the maternal variables. Nor were there any significant differences among the baselines obtained for fetal heart rate or breath-to-breath intervals prior to the presentation of three films. Preliminary analyses were conducted for all dependent variables to test for the effect of order of film presentation. As shown in Table 3, there were no significant main effects of order for any dependent variable for any of the films. Nor was there any significant

interaction effect between epochs and order for any dependent variable for any of the three films. Data were, therefore, collapsed across order prior to proceeding with further analyses.

A summary of maternal reaction scores is provided in Table 4. A repeated measures ANOVA compared maternal video reaction scores across three film segments: the labor, nature and breastfeeding films. Results of these analyses revealed there were significant differences in maternal responses, ( $F(3,29)=131.49, p<0.0001$ ). Paired- $t$  analyses showed no significant differences between maternal reactions to the breastfeeding and nature films ( $t(31)=0.51, p>0.05$ ). There were significant differences in maternal reactions to the labor film vs the nature film ( $t(31)=3.48, p<0.002$ ) and to the breastfeeding and labor film ( $t(31)=-3.45, p<0.002$ ). In summary, the self-report reaction scores for the labor film were greater than either the nature or the breastfeeding films. This result indicated that the labor film was more anxiety provoking than either the nature or breastfeeding films.

### **MATERNAL PHYSIOLOGICAL CHANGES**

#### **LABOR FILM: MATERNAL HEART RATE AND BLOOD PRESSURE**

Results from a repeated measures analysis of variance revealed there were significant differences in maternal heart rate among the four epochs (baseline and three 10s stimulus epochs),  $F(3,93)=5.36$   $p<0.002$ . There was a significant 2.5 bpm decrease from baseline in heart rate during the second epoch  $t(31)=2.36$ ,  $p<0.025$  and a significant 3.1 bpm decrease during the third 10s epoch,  $t(31)=2.85$ ,  $p<0.008$ .

Maternal blood pressures were compared across the four epochs and repeated measures ANOVA revealed there was no significant differences among these epochs,  $F(3,84)=1.78$ , n.s. The difference scores (computed for each epoch) of maternal heart rate and maternal blood pressure are shown in Figure 1.

#### **MATERNAL BREATH-TO-BREATH INTERVALS AND BREATH AMPLITUDES:**

Repeated measures ANOVA revealed there were significant differences in maternal breath-to-breath intervals among the four epochs,  $F(3,90)=12.6$ ,  $p<0.0001$ . There was a significant decrease from baseline in breath-to-breath intervals in all 3 epochs: epoch S1,  $t(31)= 5.40$ ,

$p < 0.0001$ ; epoch S2,  $t(31) = 4.19$ ,  $p < 0.0001$ ; and epoch S3,  $t(31) = 3.32$ ,  $p < 0.002$ .

As shown in Figure 2, there were no significant differences in the amplitude of maternal breaths from baseline through the stimulus period,  $F(3,81) = 1.48$ , n.s.

#### **NATURE FILM: MATERNAL HEART RATE AND BLOOD PRESSURE**

There was no significant difference in maternal heart rate among the four epochs when mothers viewed the nature film,  $F(3,93) = 2.08$ , n.s. (see Figure 3).

Repeated measures ANOVA revealed there was a difference in blood pressures among the four epochs,  $F(3,93) = 2.58$ ,  $p < 0.05$ . Further analyses revealed there was a decrease of 2.90 mm Hg in blood pressure during epoch S2 that approached significance,  $t(28) = 2.2$ ,  $p < 0.037$  but there was no difference for either of the other epochs.

#### **MATERNAL BREATH-TO-BREATH INTERVALS AND BREATH AMPLITUDES:**

Repeated measures ANOVA revealed there were no significant differences in maternal breath-to-breath intervals among the four epochs,  $F(3,90) = 0.78$ , n.s.

Figure 4 depicts difference scores computed for each 10s epoch. There were no significant differences in the amplitude of maternal breaths for any epoch,  $F(3,81) = 0.75$ ,

n.s.

#### **BREASTFEEDING FILM: MATERNAL HEART RATE AND BLOOD PRESSURE**

Repeated measures ANOVA revealed there were no significant differences in maternal heart rate among the four epochs,  $F(3,93)=1.89$ , n.s.

Repeated measures ANOVA revealed there was a significant difference in blood pressure among the four epochs,  $F(3,84)=3.5$ ,  $p<0.017$ . There was a significant 3.4 mm Hg decrease from baseline in blood pressure during epoch S2,  $t(31)=2.48$ ,  $p<0.019$  and no suggestion of a difference for either of the other epochs. Figure 5 depicts difference scores computed for each epoch.

#### **MATERNAL BREATH-TO-BREATH INTERVALS AND BREATH AMPLITUDES:**

There were significant differences in maternal breath-to-breath intervals among the four epochs revealed by repeated measures ANOVA,  $F(3,90)=3.66$ ,  $p<0.015$ . There was a significant decrease from baseline in breath-to-breath intervals during epoch S1,  $t(31)=-3.21$ ,  $p<0.003$  (see Figure 6). This decrease in breath-to-breath intervals represents an increase in respiration rate of 3 breaths per minute or a 19% change.

There were no significant differences in the amplitude of maternal breaths from baseline through the stimulus period,  $F(3,81)=0.47$ , n.s.

#### FETAL PHYSIOLOGICAL CHANGES

##### THE LABOR FILM: FETAL HEART RATE AND BREATHING MOVEMENTS:

Fetal heart rate and breathing movements were analyzed in a manner similar to that previously described for maternal dependent variables (see above).

Repeated measures ANOVA failed to reveal any significant differences in fetal heart rate among the four epochs,  $F(3,90)=0.26$ , n.s. (see Figure 7)

Due to the episodic nature of fetal breathing movements, there were only a limited number of fetal breaths available in every epoch which precluded repeated measures analysis of variance. During the labor film, there were 10 fetuses whose breathing movements were recorded during the baseline period (see Table 5). Paired- $t$  tests were conducted to examine changes from baseline. Analyses failed to reveal any significant difference from baseline for any stimulus epoch (see Figure 8).

### **THE NATURE FILM**

There were no significant differences in fetal heart rate among the four epochs revealed by repeated measures ANOVA,  $F(3,93)=1.24$ , n.s. (see Figure 9).

Again, there were only a limited number of breathing movements available for every epoch which precluded repeated measures analysis of variance (see Table 5). There were 12 fetuses whose breathing movements were recorded during the baseline period. Paired- $t$  tests failed to show any significant changes from baseline through the stimulus period (see Figure 10).

### **THE BREASTFEEDING FILM**

Repeated measures ANOVA revealed a difference in fetal heart rate among the four epochs that was marginally significant,  $F(3,81)=2.55$ ,  $p<0.06$ . There was an increase from baseline in fetal heart rate during epoch S2 (see Table 6), although this change did not reach the adjusted Bonferroni significance level of  $p<0.017$ ,  $t(31)=2.2$ ,  $p<0.039$  (see Figure 11).

During the breastfeeding film, there were 14 fetuses

whose breathing movements were recorded during the baseline period. However, there was an insufficient number of fetuses whose breathing movements continued throughout the stimulus period to conduct a repeated measures analysis of variance. Therefore, paired- $t$  tests were conducted to examine changes from baseline for each stimulus epoch. Of the 8 fetuses whose breathing movements were recorded during baseline and epoch S1, all exhibited a decrease from baseline (mean=-375 ms) in breath-to-breath intervals during the epoch,  $t(7)=-3.50$ ,  $p<0.01$  (see Figure 12). There were no significant changes in fetal breath-to-breath intervals during either of the other two epochs.

#### **MULTIPLE-REGRESSION ANALYSES OF FOUR MATERNAL PHYSIOLOGICAL VARIABLES FOR PREDICTING FETAL HEART RATE CHANGES**

In order to obtain a clearer understanding of the relationship between mothers whose physiology did change while viewing the film and fetal heart rate responses, additional analyses were conducted. Multiple-regression analyses of changes in four maternal variables (blood pressure, heart rate, breath-to-breath intervals and the amplitude of breaths) were conducted to predict changes in fetal heart rate. These analyses were performed to evaluate the correlation between maternal physiological variables and fetal heart rate for each film. Note that there is now a

reduced number of subjects because only 22 subjects had data for all of the maternal and fetal variables. Fetal breathing movements were not included in these analyses due to limited data.

The relationship between maternal and fetal physiology was analyzed by focusing on epoch S2 (second 10s stimulus epoch) because this was the only period during which there was a suggestion of a change in fetal heart rate.

As can be seen in Table 7, there was no significant correlation between the maternal physiological changes and fetal heart rate found during the labor film,  $R=0.60$ ,  $df(4,21)$ , n.s. Maternal heart rate and respiration rate changed significantly, however, the combination of maternal physiological changes during the labor film were insufficient to predict a fetal response. This finding suggests that while there were some significant changes in maternal physiology during the labor film segment presentation, the combination of maternal physiological changes during this film were insufficient to elicit a fetal response. This result also suggests that the discrete pattern of maternal physiological changes observed during the breastfeeding film contributed to eliciting the fetal heart rate change during the second 10s of that film.

In addition, there was no significant correlation between maternal physiological changes and fetal heart rate

during the nature film,  $R=0.24$   $df(4,21)$ , n.s. Note that none of the maternal physiological variables were significant in this analysis (see Table 8).

In contrast to both the labor and nature films, there was a highly significant correlation found between maternal physiological changes and fetal heart rate during the breastfeeding film,  $R=0.81$ ,  $F(4,21)=0.37$ ,  $p<0.001$ . This finding suggests that the discrete pattern of maternal physiological changes observed during the breastfeeding film contributed to eliciting the fetal heart rate change during the second 10s of that film and that each of the maternal variables was highly significant (see Table 9). Since the only film to evidence a fetal heart rate response was the breastfeeding film, the fetal heart rate changes predicted by this multiple-regression model are plotted against actual changes in Figure 13.

The data presented in Figure 13 represents the actual combined values of maternal physiological variables collected during the breastfeeding film. The multiple-regression analyses provides a model for understanding the relationship between a pattern of maternal physiological changes and fetal heart rate. As shown in Figure 13, not all of the pregnant women exhibited identical patterns of physiological responses. This model, however, illustrates that the magnitude and direction of the fetal heart rate

response is related to that of the pregnant woman's physiological changes during the breastfeeding film.

Finally, there were five highly anxious subjects whose state or trait scores were greater than 50.  $t$  tests were conducted to determine whether fetal heart rate responses were significantly different between anxious and non-anxious pregnant women. There was no significant difference between groups (anxious vs non-anxious) in fetal heart rate responses based on trait anxiety ( $t_{(30)}=0.39$ ,  $p>0.05$ ) or state anxiety ( $t_{(30)}=0.23$ ,  $p>0.05$ ), during the labor film. Similarly, there was no significant difference between groups in fetal heart rate responses based on trait anxiety ( $t_{(30)}=3.0$ ,  $p>0.05$ ) or state anxiety ( $t_{(30)}=0.70$ ,  $p>0.05$ ), during the nature film. There was no significant difference between groups in fetal heart rate responses based on trait anxiety ( $t_{(30)}=0.008$ ,  $p>0.05$ ) or state anxiety ( $t_{(30)}=1.05$ ,  $p>0.05$ ), during the breastfeeding film.

## DISCUSSION

The present investigation was conducted to examine the effects of maternal emotions associated with acute physiological changes on fetal behavior. Specifically, the focus of this study was to relate emotionally induced changes in maternal physiology to fetal heart rate and breathing.

Cardiovascular reactivity and respiratory changes have been used as indices of emotion. In this study, three films were presented to elicit differential affective responses. Previous research has shown that emotional state changes were associated with changes in physiology including blood pressure, heart rate and respiration (Ax, 1953; Bloch, Lemeignan & Aguilera, 1991; Schachter & Singer, 1962; Sinha et al., 1992).

The current results are consistent with earlier studies in which film segments elicited differential response patterns among nonpregnant adults (Hubert & de Jong-Meyer, 1990, 1991). During the labor film, which had significantly higher reactions scores than the other films, there was a significant increase in maternal respiration rate and a decrease in maternal heart rate. An increase in breathing rate is characteristic of the subjective experience of anxiety and fear (Hubert & de Jong-Meyer, 1990, 1991), while a decrease in heart rate has been attributed to an attentional response (Kagan & Rosman, 1964; Obrist, Howard,

Sutterer, Hennis & Murrell, 1973; Obrist, Webb, Sutterer & Howard, 1973).

During the nature film, there were no significant changes in maternal heart rate or respiration, which is consistent with previous reports of physiological responses to neutral stimuli (Hubert & de Jong-Meyer, 1990, 1991; Sinha et al., 1992). However, there was a significant decrease in maternal blood pressure which has been associated with the effects of a pleasant stimulus (Hubert & de Jong-Meyer, 1990).

There was a significant increase in maternal respiration rate and a significant decrease in maternal blood pressure during the breastfeeding film. The increase in maternal respiration, noted both during the labor and breastfeeding films, is characteristic of respiratory response patterns that have been associated with the subjective experience of anxiety, joy and excitement.

The blood pressure responses evidenced in this study are consistent with those found in earlier studies of nonpregnant adults (Kagan & Rosman, 1964; Lacey, Kagan, Lacey & Moss, 1963; Lacey, 1967; Obrist, Webb, Sutterer & Howard, 1970). Subjects in one of the studies exhibited a decrease in blood pressure, during visual tasks, which was interpreted as an attentional response (Kagan & Rosman, 1964). This finding suggests that the decrease in blood pressure observed in this study also may represent an

attentional response to visual stimuli. However, the blood pressure and heart rate responses recorded, during the three films, must be evaluated within the context of physiological changes specific to the third trimester of pregnancy. That is, the magnitude of the maternal cardiovascular response may have been limited by the fact that there is a 15% increase in cardiac output during pregnancy. Therefore, one might interpret the blood pressure responses evidenced in this study in terms of the law of initial values (Lacey & Lacey, 1962) which would restrict the potential magnitude of the maternal cardiovascular response due to an elevated baseline level.

The major focus of this study was confined to the immediate effects of maternal emotional and physiological changes on fetal heart rate and breathing. The results suggest that the fetus may be sensitive and reactive to acute changes in maternal physiology associated with emotion. The breastfeeding film elicited coincident changes in maternal and fetal physiology. There was a marginally significant increase in fetal heart rate concomitant with a significant increase in maternal respiration rate and a significant decrease in maternal blood pressure during this film. For those fetuses whose breathing was recorded, there was an increase in fetal breathing activity coincident with an increase in maternal respiration rate and a decrease in maternal blood pressure. However, there were no significant

changes in fetal heart rate or fetal breathing during either the nature or the labor film. Due to the episodic nature of fetal breathing, these results must be interpreted with caution (Fox, 1976; Fox & Moessinger, 1985; Jansen & Chernick, 1991; Patrick, 1982).

Although both the labor and breastfeeding films elicited an increase in maternal respiration rate, fetal heart rate and breathing increased only during the breastfeeding film. As maternal emotions shift from baseline, there are multiple maternal physiological changes in heart rate, blood pressure and respiration that may affect the fetus. The fetus simultaneously experiences all of the maternal physiological changes associated with maternal emotions. Therefore, the relationship between maternal physiological changes and fetal behavior was analyzed by multiple-regression analyses. The results of these analyses revealed there was a specific pattern of maternal physiological changes that predicted fetal heart rate changes. Namely, an increase in maternal respiration rate, heart rate and a decrease in blood pressure and amplitude, accounted for 66% of the variance in fetal heart rate changes. Neither the nature nor the labor films elicited the same maternal physiological response pattern.

These results suggest that fetuses appear to be sensitive to a specific combination of maternal physiological responses. However, this does not preclude

the possibility that there may be other factors, such as maternal catecholamines or cortisol, that may have been released during this period and triggered the fetal response.

While the connection between maternal emotions and fetal behavior appears to be a complex interaction, the fetal response suggests there are several potential mechanisms that may contribute to the way in which maternal emotions are conveyed to the fetus. For example, the fetal response to stress is mediated by catecholamines. However, given the rapid fetal response observed in this study (within a 30s framework), these findings suggest that this finding is independent of maternal catecholamines.

There are other sources of maternal physiological changes which may have induced such a fast fetal response. Namely, fetal adrenal cells are sensitive to changes in cortisol levels. During fetal life, the adrenal cortex is larger than that of the adult (Reece et al., 1995) and the secretion of adrenocorticotropic hormone (ACTH) and *B*-endorphin are controlled by corticotrophin releasing factor (CRF).

Maternal CRF is produced in the placenta and the level of maternal CRF increases toward the end of pregnancy and may thereby provide a source for the fetus. Maternal cortisol readily cross the placenta and is rapidly converted to cortisone by the fetus (Reece et al., 1995). While the

sympathetic nervous system, in combination with the adrenal medulla, appears to coordinate the cardiovascular system of the adult, the adrenal medulla plays a primary role in coordinating fetal responses. There is evidence in the literature that the fetus is influenced by the presence of maternal cortisol (Oltras, Mora & Vives, 1987; Sandman, Wadhwa, Dunkel-Schetter, Chicz-DeMet, Belman, Porto, Murata, Garite & Crinella, 1994; Wadhwa, Sandman, Porto, Dunkel-Schetter & Garite, 1993;). Thus, one might hypothesize that an increase in maternal cortisol and CRF levels may have transduced information about its mother's environment to the fetus. Furthermore, a sudden increase in maternal cortisol and CRF levels may have been a reflection of the mother's emotional reaction to the film which may have initiated the increase in fetal heart rate. Indeed, the presence of increased levels of placental CRF may play an important role in mediating maternal emotions and the activation of the fetal HPA axis.

The increase in fetal heart rate exhibited in this study also may have been related to the effects of mechanical stimulation associated with rapid respiration rates. There is evidence that the fetus is sensitive and reactive to increases in maternal respiration. Recently, investigators demonstrated that fetuses are sensitive to maternal displacement associated with maternal rocking (Porton-Deterne, Jacquet & Lecanuet, 1996). There was an

increase in fetal heart rate, coincident with an increase in maternal respiratory rate, as pregnant women were rocked in a rocking-chair (Porton-Deterne, personal communication, 1996). In another study, fetuses were shown to be sensitive to pressure changes (Porton-Deterne, LeDu, Jacquet & Lecanuet, 1996). Fetuses exhibited an increase in heart rate in response to sustained pressure on the fetal hip via the maternal abdomen.

Additionally, it has been shown that uterine contractions provide a significant source of fetal stimulation. During uterine contractions, amniotic fluid pressure is displaced which squeezes the fetus and elicits an increase in fetal heart rate (Nathanielsz, 1995). If the fetus is sensitive to uterine contractions, then perhaps the fetus is also responsive to increases in the frequency of maternal respiratory muscle contractions.

The above-mentioned studies lend support to the notion that fetuses may be sensitive to sudden increases in maternal respiration. This explanation becomes more plausible when one considers that multiple-regression analyses revealed a highly significant increase in maternal respiration rate during the breastfeeding film. As maternal breathing became faster, the frequency of maternal diaphragmatic and respiratory muscle contractions increased. The effects of these maternal changes would be further enhanced by the fact that, during the third trimester, there

is a decrease in the amount of amniotic fluid surrounding the fetus which places the fetus in direct contact with the maternal abdominal wall. This increase in maternal diaphragmatic and respiratory muscle movements would provide the fetus with immediate sensory stimulation.

From these findings, one can conclude that an increase in maternal respiratory rate and a decrease in maternal breath amplitude were among the factors that contributed to the fetal response. The impact of these findings may be better understood by considering the influence of maternal blood pressure changes such as those observed during the breastfeeding film. The simultaneous decrease in blood pressure and an increase in respiration may be important since there is evidence that shows that the fetus is sensitive to changes in maternal blood flow (Myers, 1975).

Oxygen is delivered to the fetus via blood flow which transits from the maternal uterine artery to the placenta (Myers, 1975, 1977; Myers, Stange, Joelsson, Huzzell & Wussow, 1977). The fetus is reactive to a chronic reduction in maternal blood flow levels (Daniel, Stark, Myers, Tropper & Kim, 1996). When the normal expansion of maternal blood volumes was restricted, during the second half of pregnancy in near-term fetal sheep, there was a reduction in the distribution of oxygen and a decrease in fetal heart rate and blood pressure in this chronic preparation. This study demonstrates the importance of adequate oxygenation of the

fetus. More acute effects of blood flow reductions on fetal reactivity have been provided in studies which have examined the effects of occlusion of the umbilical vein (James, Yeh, Morishima, Daniel, Caritis, Niemann & Indyk, 1975; Wilkening & Meschia, 1991). For example, during labor, the near-term fetus exhibits an increase in heart rate in response to a reduction in blood flow from the placenta (James et al., 1975). In combination, these studies show that the fetus responds in a compensatory manner to a reduction in blood flow similar to the decrease in maternal blood pressure observed in this study.

Furthermore, certain patterns of fetal behavior may emerge to compensate for changes in oxygen availability. Thus, any event which might signal a reduction in oxygen levels ought to initiate a similar fetal response. While the evidence from this study shows that the fetus is sensitive to a specific set of maternal physiological changes, other mechanisms by which the fetus senses changes in maternal emotions and physiology remain to be explored.

One might speculate that repeated exposure to acute changes in maternal emotions and physiology, such as observed in this study, may initiate changes in fetal behavior which facilitates the development of skills necessary for the neonate to adapt to its environment. One might explore the influence of prenatal experience with maternal physiological changes associated with emotions by

examining fetal reactivity (fetal heart rate and behavior) in different contexts throughout the course of gestation.

Recently, fetal cardiac activity has been investigated in order to explore the relationship between fetal and neonatal patterns of behavior. For example, fetuses that exhibited sustained elevations in heart rates, during the latter part of gestation, had a greater incidence of subsequently being labelled as temperamentally difficult infants (Snidman, Kagan, Riordan & Shannon, 1995).

Temperament is characterized by a relatively stable set of behavioral responses. Inhibited children are reticent and avoidant in their approach to novel situations, whereas uninhibited children are spontaneous individuals who eagerly approach new situations (Kagan, 1994).

There are also individual differences in the physiological basis of each behavioral pattern, such as that noted among fetuses (Snidman et al., 1995). Those fetuses that sustained an elevated heart rate were more likely to develop into an inhibited child, whereas fetuses that exhibited greater heart rate variability were more likely to develop into an uninhibited child (Kagan, 1996). Therefore, in order to more fully explore the influence of maternal psychological and physiological and the development of neonatal temperament, it would be interesting to compare the psychological and physiological state of those women whose fetuses evidenced sustained elevations in heart rate, (who

were subsequently labelled as temperamentally difficult), with those fetuses with normal heart rate patterns. Perhaps, fetal cardiac activity is a reflection of the mother's experience of her environment. Repeated exposure to maternal responses to the environment may signal fetal behavioral responses that facilitate the development of adaptive capacities that extend to the neonate. Thus, fetal heart rate could serve as an index by which one might predict neonatal temperament

Temperament has been defined as a combination of an individual's genetic composition and experience with its environment (Kagan, 1996). Fetal behavior and development is also related to the combination of the fetus' unique genetic composition and experience with sensory stimulation within the amniotic compartment, which includes maternal physiological changes associated with emotion. If fetal behavior may be modified by maternal physiological changes associated with emotion, then perhaps the fetal behavioral repertoire serves to enhance the development of neonatal temperament (Piontelli, 1992; Snidman et al., 1995).

This raises interesting questions with regard to individual differences in maternal physiology related to emotional states. Namely, there are individual differences in neuroendocrine reactivity. For example, depressed individuals have elevated basal cortisol levels (Fox, 1994) which suggests that the fetus of a depressed pregnant woman

may be exposed to higher levels of cortisol as compared with that of a non-depressed pregnant woman. Therefore, one must evaluate fetal reactivity within the context of the maternal physiological and psychological state in which the fetus develops. Individual variation in the physiological substrate of each pregnant woman may play a critical role in the development of fetal behavioral patterns that may foreshadow the development of neonatal behaviors and temperament.

Among the many studies that have examined the role of prenatal experience with sensory information, those studies that have focused on neonatal language acquisition have provided the most provocative evidence for prenatal learning. The amniotic compartment is the first language environment in which the fetus gains experience with the auditory and physiological aspects associated with maternal speech. However, language production involves more than mere sounds. Emotions are conveyed in the prosodic structure of language which the fetus experiences as changes in the rhythm, intonation and melodic contour which facilitate the expression of emotion.

Recently, investigators demonstrated that pre-term infants (32 weeks gestational age) showed reliable cardiac decelerations when presented with contour-violating melodies that introduced novel frequencies (Morrongiello & Fenwick, 1996). This result shows that pre-term infants are sensitive

to frequency information which is encoded and later used to recall the notes of a melody. This finding suggests that if the pre-term infant has the capacity to discriminate unique melodic patterns, then the near-term fetus may share this ability to retain and recall memories of maternal physiological response patterns that occur coincident with emotional states. Based on these findings, one might hypothesize that fetuses may form contingent associations between maternal physiological response patterns (associated with emotion) and speech that the neonate may use as a key to unlock maternal emotional intent embedded in speech.

Results of a recent study which investigated the infant's ability to discriminate among various emotions showed that infants preferred happy vocal expressions embedded in their native language (Mastropieri, 1996). The results of this study allow one to infer a relationship between prenatal experience with maternal speech and the development of a neonatal discrimination of emotionally embedded speech. This study did not attempt to investigate the physiological relationship between maternal emotions and fetal behavior.

The present study, however, provides a window through which we might further explore the relationship between maternal physiological responses associated with emotion and fetal behavior. Fetal reactivity to maternal emotional and physiological changes throughout gestation provides

experience that may be important for the development of behavioral responses that will be used by the newborn. The ability of the fetus to respond to sudden changes in maternal physiology also may be a sensitive index for predicting the neonate's ability to adapt to its environment. Furthermore, prenatal experience with maternal emotions may play a pivotal role in the development of future maternal/infant interactions. Specifically, mothers have been shown to regulate their offspring's behavior such that the bidirectional nature of the maternal/infant behavioral interaction is necessary for maintaining homeostasis of the newborn (Alberts & May, 1984).

Hofer (1996) hypothesized the existence of "hidden regulators" which are experienced during the course of mother/infant interaction as either synchronous or dissonant events. If newborns are subject to hidden regulators encoded within the repetitious cycle of maternal/infant interaction, perhaps these originate during the gestational period.

As the mother experiences her environment, there are physiological changes which are transduced to the fetus by means of changes in uterine blood flow and oxygen levels. Maternal physiological changes may convey a message to the fetus by restricting blood flow and oxygen which may signal one of two behavioral responses. First, the fetus may exhibit an increase in heart rate to compensate for the decrease in oxygen. Second, the fetus may minimize its

movement to conserve oxygen levels. Regardless of which strategy the fetus employs, these early maternal/fetal interactions may serve as the hidden regulators from which maternal/infant interactions may later emerge.

Just as maternal/infant interactions regulate infant physiology and behavior (Hofer, 1996), so too, maternal physiological changes associated with emotion may regulate other fetal behaviors. For example, maternal stress may be conveyed to the fetus by an increase in maternal cortisol levels. Maternal cortisol levels regulate fetal activity, as indexed by an increase in fetal heart rate. The fetus' ability to respond adaptively to maternal physiological response patterns reinforces the relationship between maternal physiological changes and fetal behavior. Repeated exposure to maternal physiological response patterns associated with emotion may regulate fetal behavior. Hidden regulators may be encoded throughout gestation and serve as the foundation for the cyclical behavioral pattern found in maternal/infant interactions.

In conclusion, this study was conducted to explore the effects of acute changes in maternal emotions on fetal behavior. This study has uncovered a relationship between acute maternal emotions and fetal behavior. The evidence demonstrates that fetuses are reactive to maternal physiological changes during emotional events. However, the extent to which fetal development is buffered from maternal

anxiety remains to be explored. Furthermore, the data suggests that fetal development may, in fact, benefit from physiological changes associated with positive maternal emotions. The literature is extensive regarding the negative influence of prenatal stress exposure and fetal development. However, relatively little is known regarding the benefit of positive maternal emotions on fetal development.

Fetal development occurs within an environment which is subject to a constellation of maternal physiological events which both modify and regulate fetal behavior and development. Repeated prenatal exposure to maternal physiological response patterns associated with both positive and negative emotions may be essential for the development of adaptive behaviors that ensure a homeostatic physiological state in the infant.

Indeed, if the origin of infant attachment rests on the infant's ability to respond to direct maternal regulation, whose response in turn regulates its mother's behavior (Hofer, 1996); then, perhaps the fetal behavioral responses to maternal physiological changes associated with emotion may function in a similar manner. Just as the infant's behavior regulates maternal behavior, fetal responses to maternal physiological changes associated with emotion may, in turn, affect the mother. For example, the onset of labor has been shown to be initiated by an increase in the fetal

cortisol levels (Nwosu, Wallach & Bolognese, 1976). This evidence demonstrates that fetal physiology also may direct changes in maternal behavior. The relationship between maternal physiology and fetal behavior may be understood in terms of the maternal/infant interaction in which both mother and infant (or mother and fetus) plays a role in regulating the relationship.

Further exploration of the relationship between maternal physiological responses associated with emotion and the regulation of fetal behavior may continue to uncover hidden regulators and their role in fetal and neonatal development. If maternal physiology and behavior can regulate the physiological and behavioral development of the neonate, then perhaps, the regulatory relationship begun in utero provides a basis for the development of neonatal attachment, temperament and language.

**APPENDIX I: TABLES**

**TABLE 1 - MATERNAL STATE/TRAIT SCORES**

SUBJECT #	STATE SCORE	TRAIT SCORE
1	35	36
2	37	36
3	48	51
4	58	58
5	35	28
6	28	30
7	30	29
8	21	26
9	35	38
10	37	35
11	26	28
12	38	37
13	31	34
14	48	43
15	31	28
16	30	25
17	33	30
18	25	26
19	48	49
20	31	31
21	48	43
22	31	30
23	30	23
24	40	28
25	48	53
26	58	61
27	52	64
28	44	38
29	30	34
30	38	45
31	28	31
32	43	48
MEAN	37.3	37.4
SD	8.4	11.2

\*Score&gt;50=anxiety

**TABLE 2****BASELINE VALUES OF MATERNAL AND FETAL DEPENDENT VARIABLES**

<b>LABOR</b>	<b>Mean MHR (bpm) 91.5</b>	<b>Mean MBP (mmHg) 109.7</b>	<b>Mean BTB (ms) 3.1</b>	<b>Mean MAMP 412.23</b>	<b>Mean FHR (bpm) 134.29</b>	<b>Mean FBRM (ms) 1.30</b>
	<b>SEM 1.6</b>	<b>SEM 2.5</b>	<b>0.1</b>	<b>32.84</b>	<b>1.28</b>	<b>0.11</b>
<b>NATURE</b>	<b>Mean 90.9</b>	<b>Mean 109.5</b>	<b>3.3</b>	<b>423.62</b>	<b>134.82</b>	<b>1.32</b>
	<b>SEM 1.7</b>	<b>SEM 2.6</b>	<b>0.2</b>	<b>41.17</b>	<b>1.29</b>	<b>0.07</b>
<b>BREAST</b>	<b>MEAN 90.2</b>	<b>Mean 109.3</b>	<b>3.2</b>	<b>430.52</b>	<b>133.26</b>	<b>1.52</b>
	<b>SEM 1.6</b>	<b>SEM 2.5</b>	<b>0.1</b>	<b>41.86</b>	<b>1.53</b>	<b>0.11</b>

**MATERNAL HEART RATE** = MHR  
**MATERNAL BLOOD PRESSURE** = MBP  
**MATERNAL BREATH-TO-BREATH INTERVALS** = BTB  
**MATERNAL AMPLITUDE OF BREATHS** = AMP  
**FETAL HEART RATE** = FHR  
**FETAL BREATHING MOVEMENTS** = FBRM

TABLE 3

EFFECTS OF FILM ORDER PRESENTATION

## THE LABOR FILM:

MATERNAL VARIABLE	MAIN EFFECT OF ORDER	EPOCH X ORDER
HEART RATE	F(1,30)= 0.65, n.s.	F(3,90)=1.21, n.s.
BLOOD PRESSURE	F(1,27)= 3.04, n.s.	F(3,81)=1.72, n.s.
BREATH-TO-BREATH INTERVAL	F(1,29)= 1.90, n.s.	F(3,87)=0.52, n.s.
AMPLITUDE	F(1,26)= 1.92, n.s.	F(3,78)=0.38, n.s.

## THE NATURE FILM:

MATERNAL VARIABLE	MAIN EFFECT OF ORDER	EPOCH X ORDER
HEART RATE	F(1,30)= 0.05, n.s.	F(3,90)=0.57, n.s.
BLOOD PRESSURE	F(1,30)= 1.84, n.s.	F(3,81)=1.32, n.s.
BREATH-TO-BREATH INTERVAL	F(1,26)= 1.42, n.s.	F(3,87)=1.54, n.s.
AMPLITUDE	F(1,26)= 0.94, n.s.	F(3,78)=0.78, n.s.

## THE BREASTFEEDING FILM:

MATERNAL VARIABLE	MAIN EFFECT OF ORDER	EPOCH X ORDER
HEART RATE	F(1,30)= 0.59, n.s.	F(3,90)=1.09, n.s.
BLOOD PRESSURE	F(1,30)= 1.84, n.s.	F(3,81)=1.32, n.s.
BREATH-TO-BREATH INTERVAL	F(1,29)= 1.97, n.s.	F(3,87)=1.87, n.s.
AMPLITUDE	F(1,26)= 1.14, n.s.	F(3,78)=0.83, n.s.

**TABLE 4**

SUBJECT	VIDEO REACTION SCORES		
	BREASTFEEDING	NATURE	LABOR
1	5	5	5
2	7	8	11
3	8	12	13
4	8	8	10
5	5	5	8
6	8	5	5
7	8	7	11
8	8	7	11
9	8	7	15
10	7	5	12
11	5	5	5
12	10	8	11
13	5	5	5
14	5	8	8
15	8	8	5
16	5	5	7
17	10	8	12
18	8	7	8
19	11	8	11
20	5	14	11
21	11	8	8
22	10	11	8
23	5	5	8
24	5	5	5
25	8	8	10
26	5	7	10
27	7	8	8
28	5	5	8
29	5	5	7
30	11	14	11
31	7	5	7
32	11	8	10
	$\bar{X}=7.25$ $SD=2.2$	$\bar{X}=7.0$ $SD=0.39$	$\bar{X}=8.6$ $SD=0.5$

**TABLE 5**

**SUMMARY OF THE NUMBER OF FETUSES  
WHOSE BREATHING WAS RECORDED FOR EACH EPOCH**

	<b>BASELINE</b>	<b>S1</b>	<b>S2</b>	<b>S3</b>
<b>LABOR</b>	<b>10</b>	<b>10</b>	<b>11</b>	<b>11</b>
<b>NATURE</b>	<b>12</b>	<b>9</b>	<b>13</b>	<b>12</b>
<b>BREASTFEEDING</b>	<b>14</b>	<b>13</b>	<b>12</b>	<b>13</b>

**SUMMARY OF THE NUMBER OF FETUSES  
WHOSE BREATHING MOVEMENTS BEGAN AFTER THE BASELINE PERIOD**

		<b>S1</b>	<b>S2</b>	<b>S3</b>
<b>LABOR</b>	<b>-</b>	<b>3.0</b>	<b>2.0</b>	<b>1.0</b>
<b>NATURE</b>	<b>-</b>	<b>-</b>	<b>2.0</b>	<b>2.0</b>
<b>BREASTFEEDING</b>	<b>-</b>	<b>-</b>	<b>2.0</b>	<b>2.0</b>

**TABLE 6**

**FETAL HEART RATE DURING 10S EPOCHS  
PRIOR TO AND DURING THE BREASTFEEDING FILM**

<b>SUBJECT</b>	<b>BASELINE</b>	<b>S1</b>	<b>S2</b>	<b>S3</b>
1	127	120	124	128
2	128	130	131	133
3	126	132	133	136
4	151	151	152	153
5	132	128	133	134
6	132	133	144	143
7	133	134	135	137
8	133	132	135	134
9	138	135	138	138
10	127	128	128	131
11	129	124	124	131
12	115	128	115	118
13	131	132	131	127
14	144	144	145	138
15	142	142	141	143
16	132	133	134	134
17	141	141	139	140
18	128	124	134	128
19	153	158	152	150
20	138	138	144	137
21	128	131	128	130
22	127	128	128	128
23	148	148	146	147
24	120	123	131	128
25	127	121	127	123
26	123	122	120	120
27	138	130	128	127
28	128	130	135	138
29	135	133	131	135
30	142	142	143	143
31	132	133	135	133
32	123	128	128	127

**TABLE 7**  
**A MULTIPLE-REGRESSION MODEL**  
**FOR PREDICTING FETAL HEART RATE CHANGES DURING EPOCH S2**  
**BASED ON FOUR MATERNAL PHYSIOLOGICAL CHANGES**

**LABOR FILM**

OVERALL N=22                      **R=0.60**                      **F(4,17)=2.31**    **p<0.10**

<b><u>SOURCE</u></b>	<b><u>COEFFICIENT</u></b>	<b><u>SEM</u></b>	<b><u>t</u></b>	<b><u>p&lt;</u></b>
CONSTANT	1.404	0.941	1.49	0.15
MBP	0.078	0.104	0.19	0.46
MHR	0.227	0.107	2.12	0.05
MRESP-RATE	0.992	1.658	0.59	0.55
AMPLITUDE	-0.016	0.006	-2.70	0.01

**TABLE 8**  
**A MULTIPLE-REGRESSION MODEL**  
**FOR PREDICTING FETAL HEART RATE CHANGES DURING EPOCH S2**  
**BASED ON FOUR MATERNAL PHYSIOLOGICAL CHANGES**

**NATURE FILM**

OVERALL N=26                      R=0.24                      F(4,17)=0.32                      p<0.86

<b>SOURCE</b>	<b>COEFFICIENT</b>	<b>SEM</b>	<b>t</b>	<b>p&lt;</b>
<b>CONSTANT</b>	<b>-0.145</b>	<b>0.827</b>	<b>-0.17</b>	<b>0.86</b>
<b>MBP</b>	<b>0.022</b>	<b>0.108</b>	<b>0.20</b>	<b>0.84</b>
<b>MHR</b>	<b>0.068</b>	<b>0.114</b>	<b>0.59</b>	<b>0.55</b>
<b>MRESP-RATE</b>	<b>-0.383</b>	<b>0.683</b>	<b>-0.56</b>	<b>0.58</b>
<b>AMPLITUDE</b>	<b>-0.001</b>	<b>0.008</b>	<b>-0.09</b>	<b>0.92</b>

**TABLE 9**  
**A MULTIPLE-REGRESSION MODEL**  
**FOR PREDICTING FETAL HEART RATE CHANGES DURING EPOCH S2**  
**BASED ON FOUR MATERNAL PHYSIOLOGICAL CHANGES**

**BREASTFEEDING FILM**

OVERALL N=22

R=0.81

F(4,17)=8.36 p<0.001

<b><u>SOURCE</u></b>	<b><u>COEFFICIENT</u></b>	<b><u>SEM</u></b>	<b><u>t</u></b>	<b><u>p&lt;</u></b>
CONSTANT	2.496	0.407	6.12	0.00
MBP	0.139	0.048	2.89	0.01
MHR	0.181	0.076	2.38	0.02
MRESP-RATE	1.495	0.490	3.05	0.007
AMPLITUDE	-0.013	0.003	-4.20	0.001

**APPENDIX II: FIGURES**

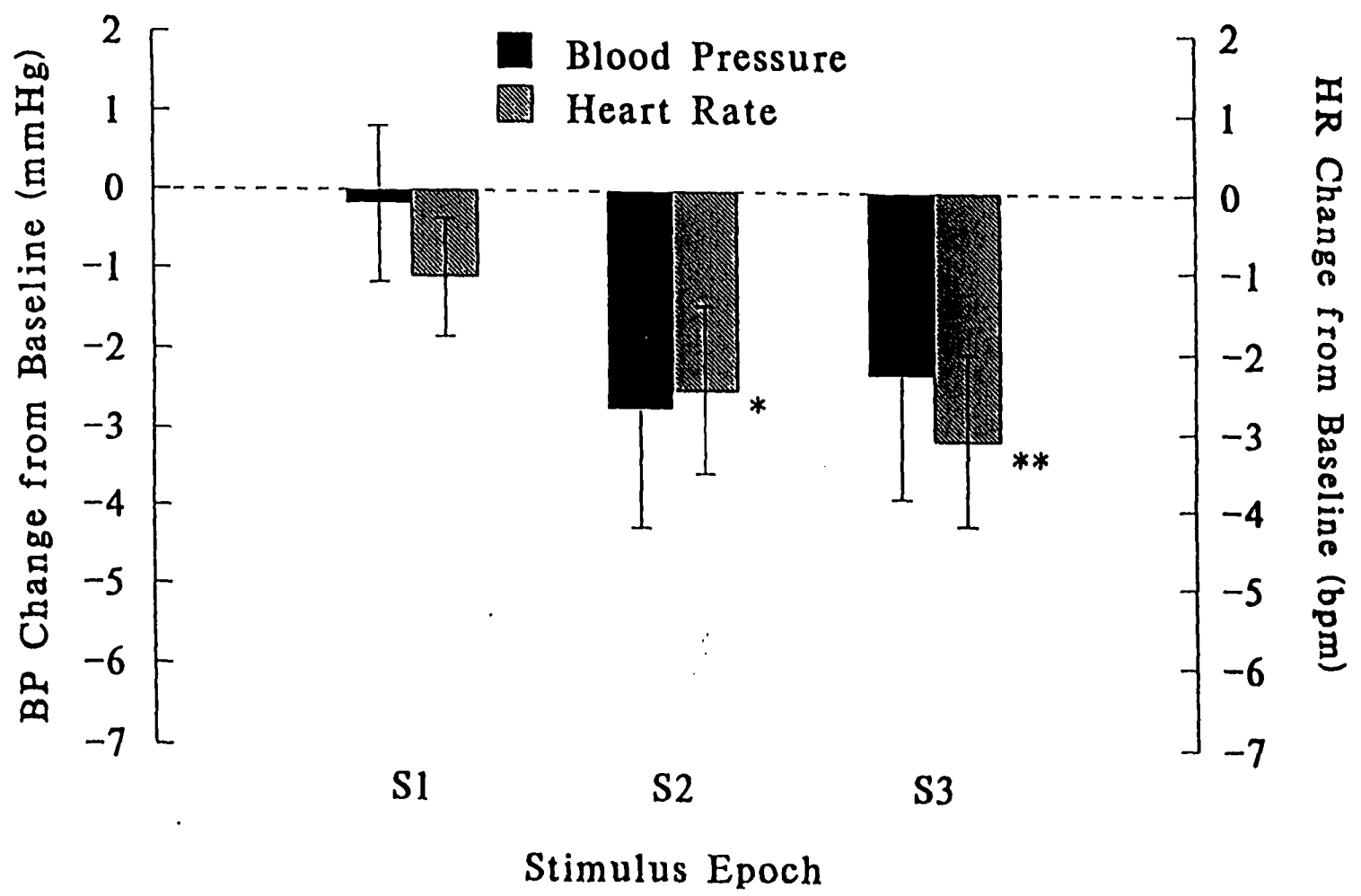
...

**FIGURE 1**

**Mean changes from baseline in maternal blood pressure (mm Hg) and maternal heart rate (bpm) in three 10s epochs during the labor film**

# Changes in Maternal BP and HR While Viewing Labor Film

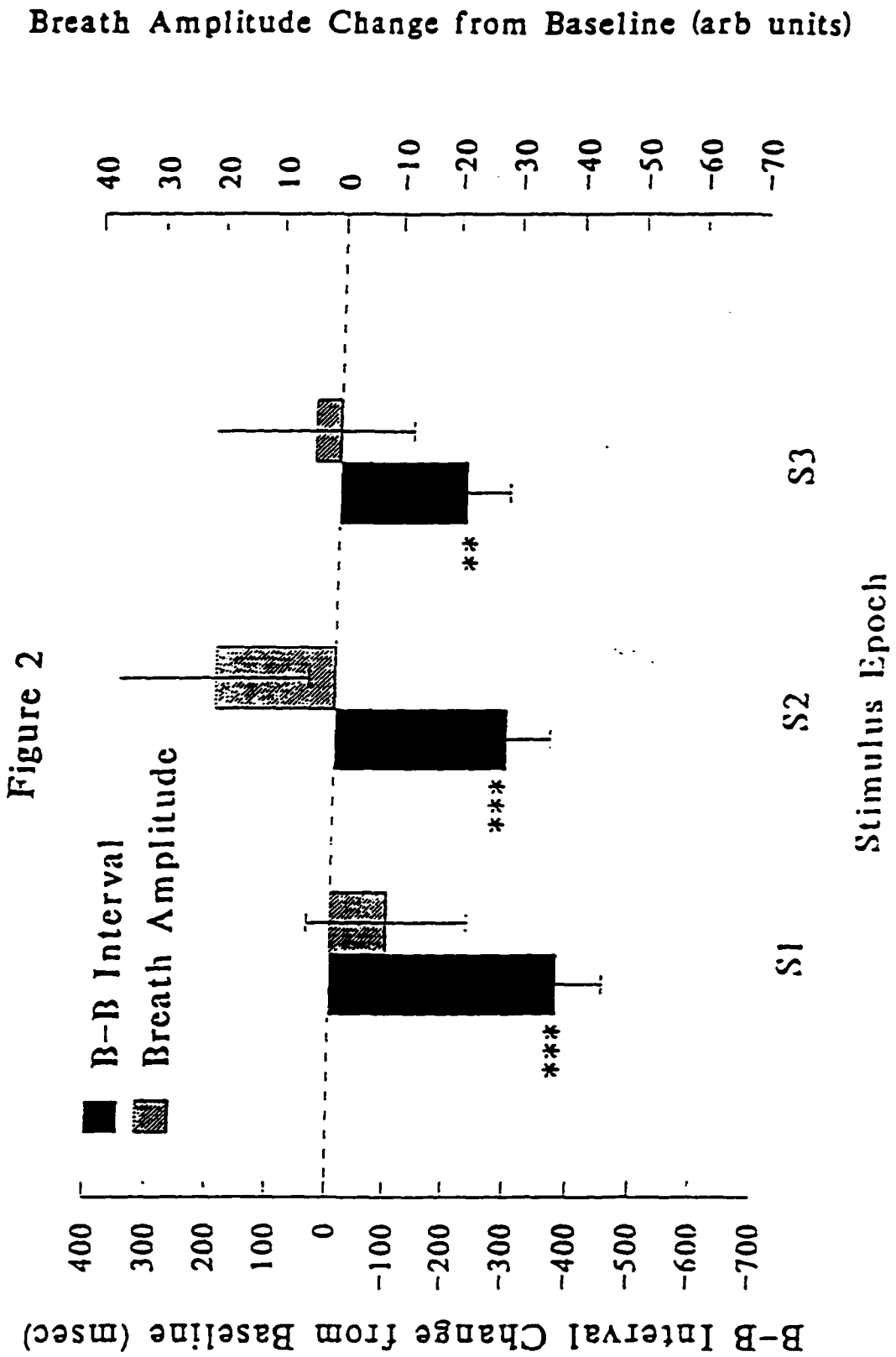
Figure 1



**FIGURE 2**

**Mean changes from baseline in maternal breath-to-breath intervals and breath amplitude in three 10s epochs during the labor film.**

Changes in Maternal Respiration While Viewing Labor Film

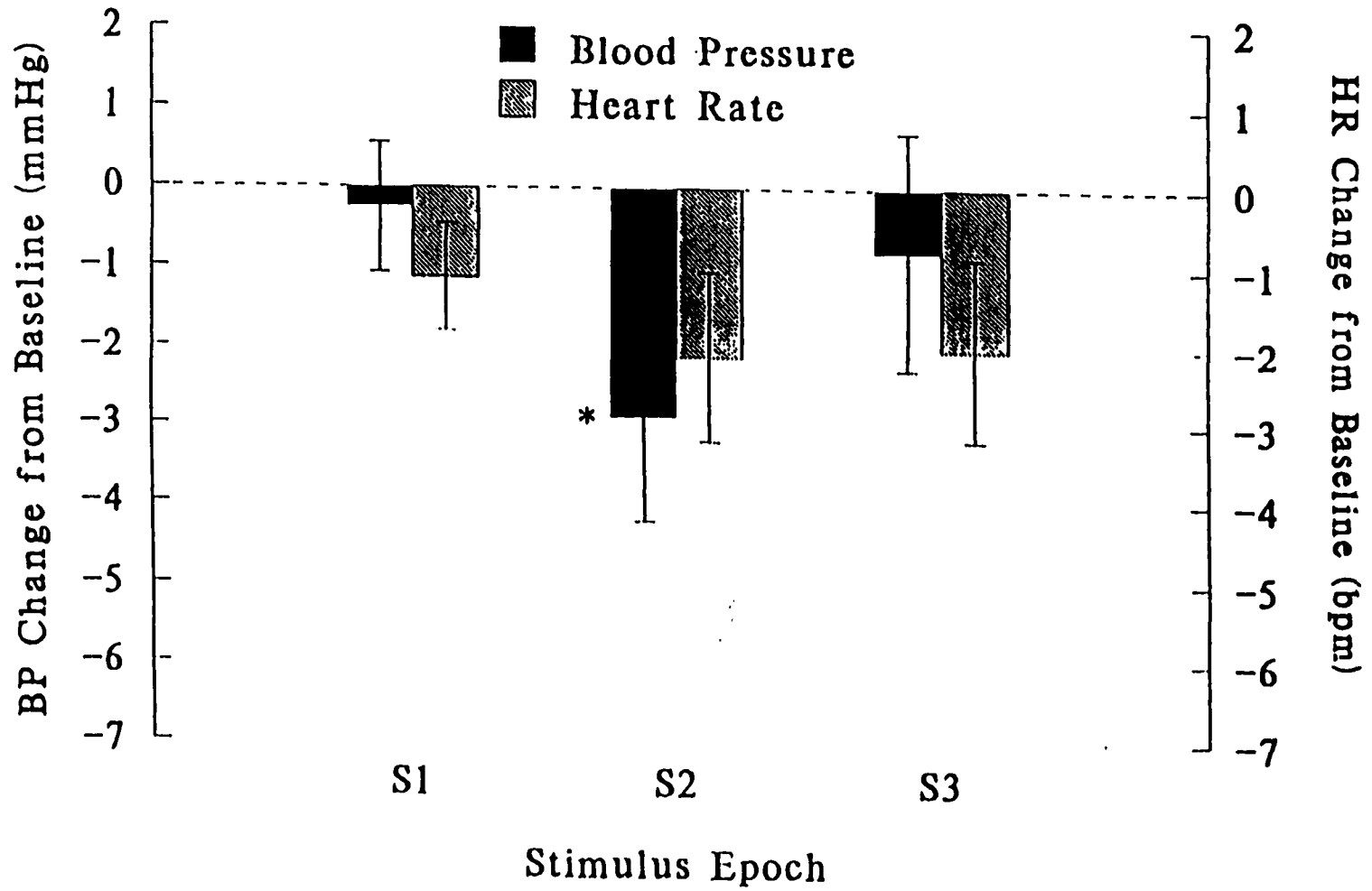


**FIGURE 3**

**Mean changes from baseline in maternal blood pressure (mm Hg) and maternal heart rate (bpm) in three 10s epochs during the nature film.**

# Changes in Maternal BP and HR While Viewing Nature Film

Figure 3

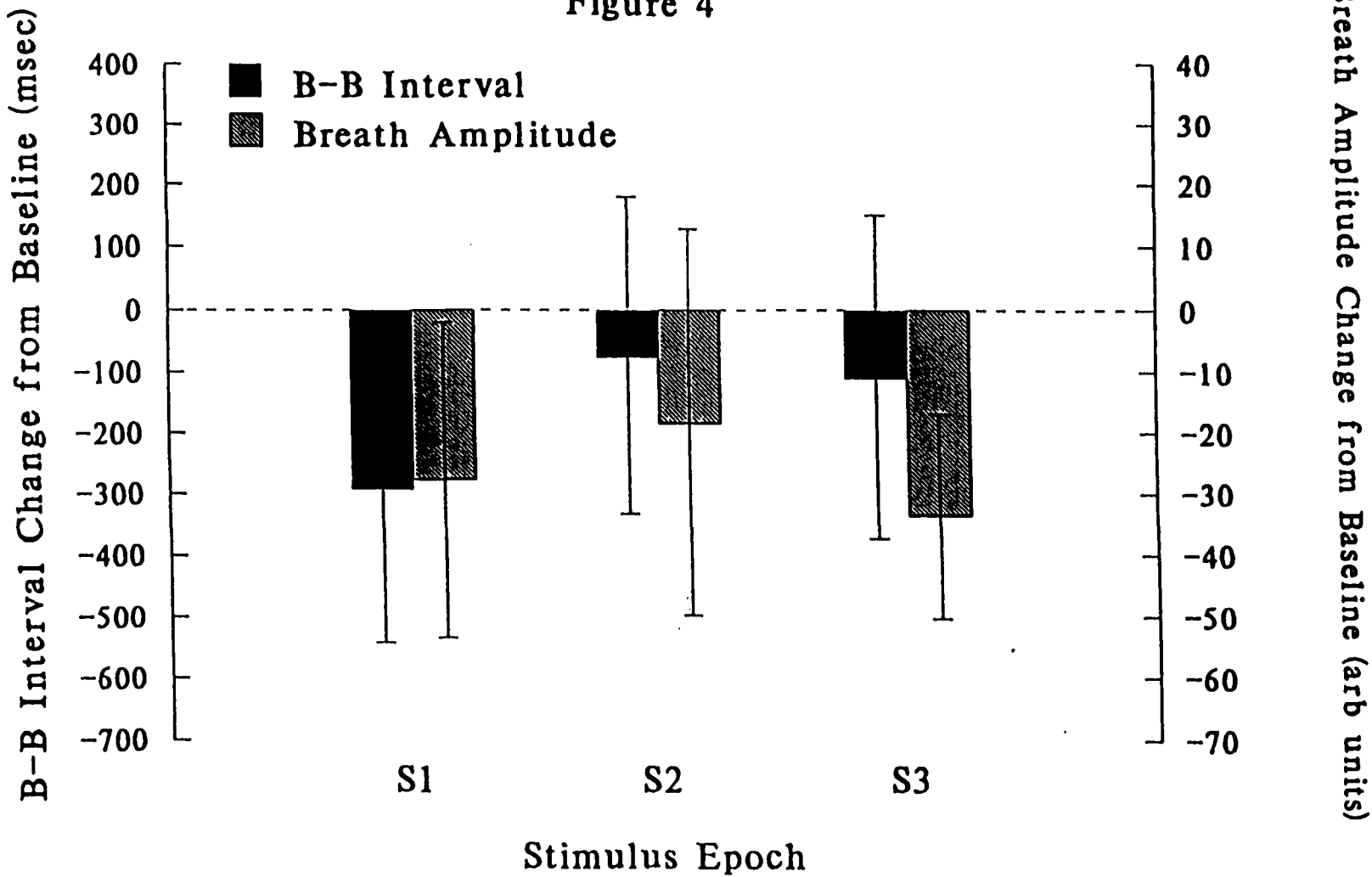


**FIGURE 4**

**Mean changes from baseline in maternal breath-to-breath intervals and breath amplitude in three 10s epochs during the nature film.**

# Changes in Maternal Respiration While Viewing Nature Film

Figure 4

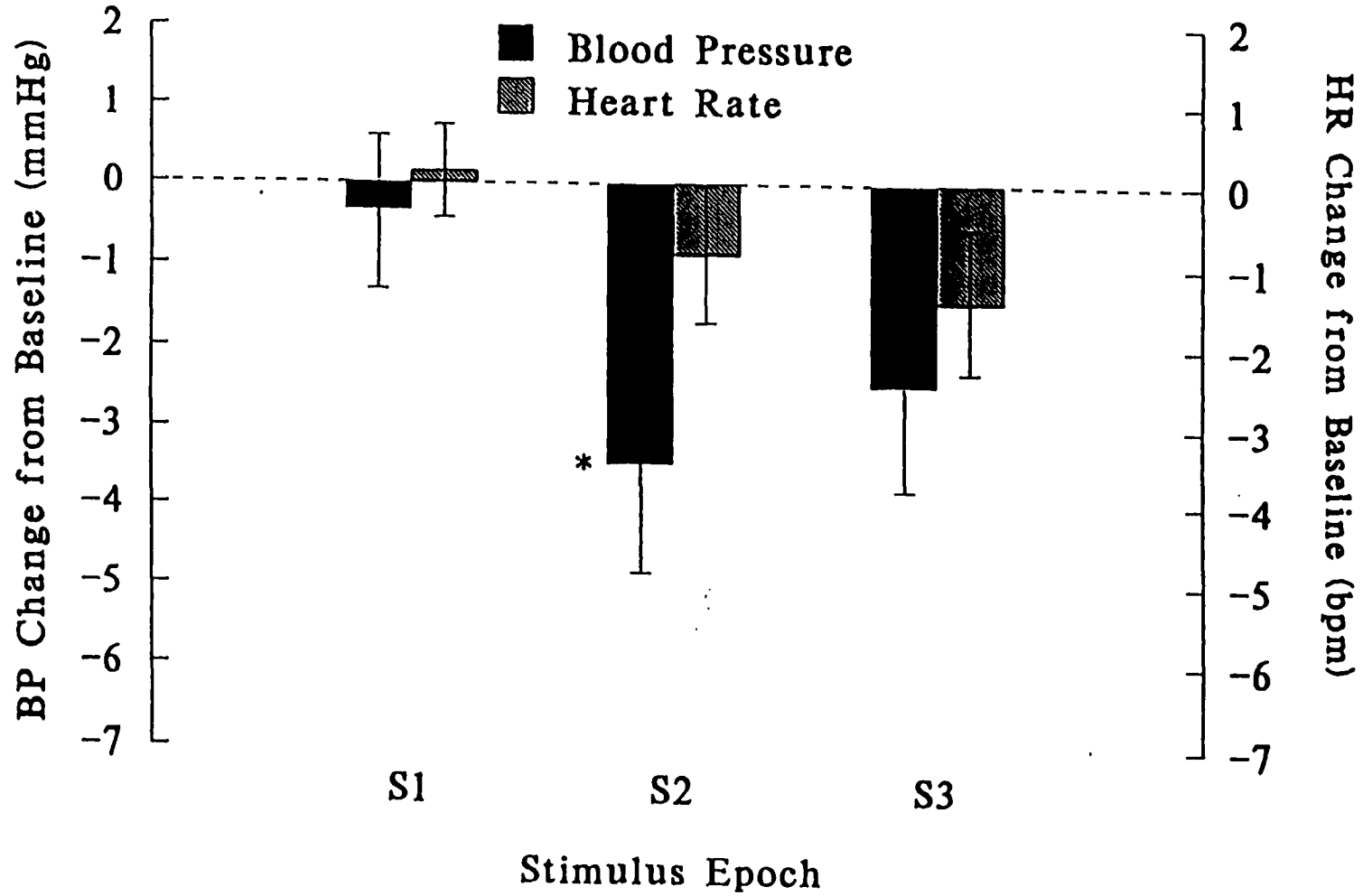


**FIGURE 5**

**Mean changes from baseline in maternal blood pressure (mm Hg) and maternal heart rate (bpm) in three 10s epochs during the breastfeeding film.**

# Changes in Maternal BP and HR While Viewing Breastfeeding Film

Figure 5

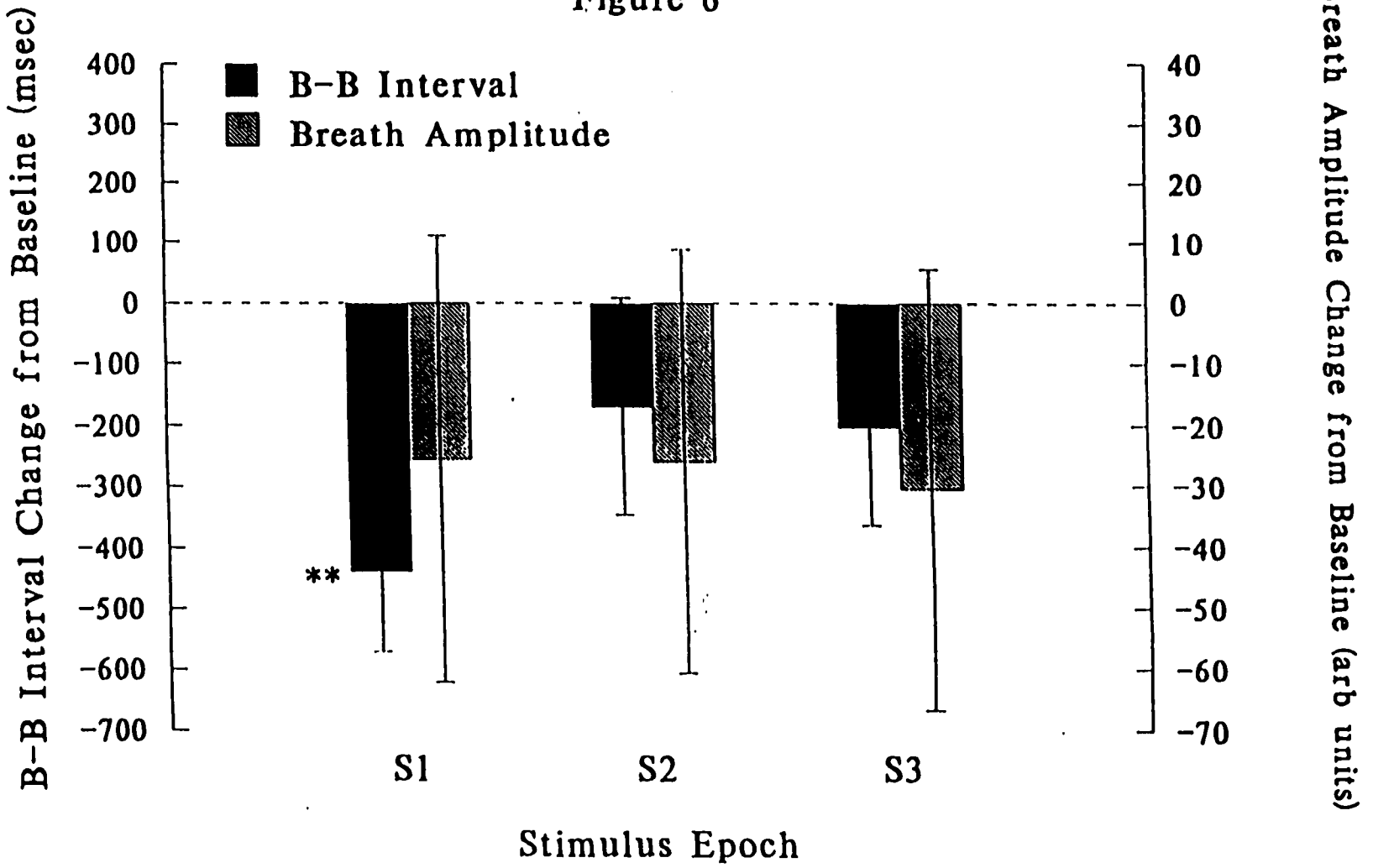


**FIGURE 6**

**Mean changes from baseline in maternal breath-to-breath intervals and breath amplitude in three 10s epochs during the breastfeeding film.**

# Changes in Maternal Respiration While Viewing Breastfeeding Film

Figure 6

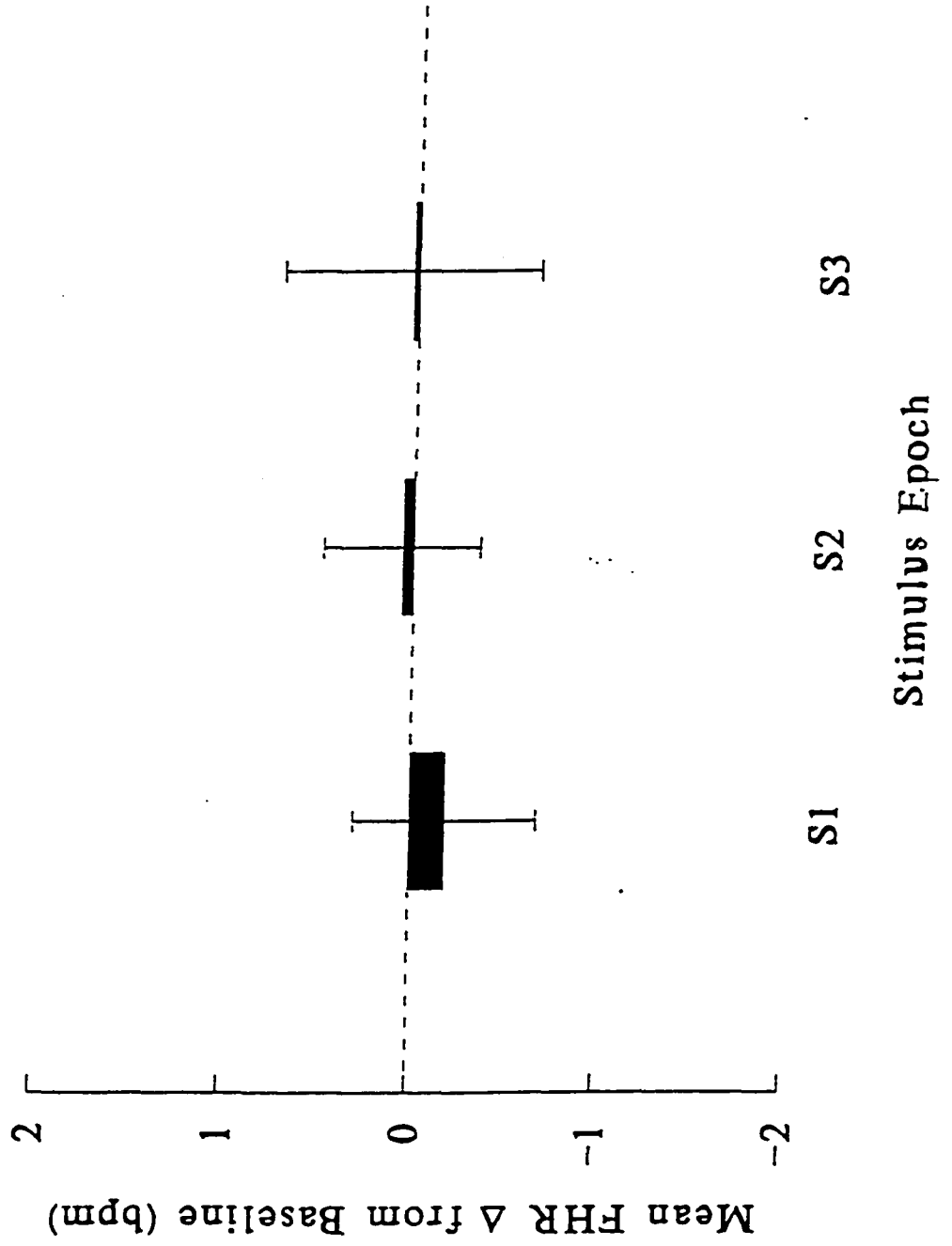


**FIGURE 7**

**Mean changes from baseline in fetal heart rate (bpm)  
in three 10s epochs during the labor film.**

# Mean Changes in FHR With Mother Viewing Labor Film

Figure 7



S1

S2

S3

Mean FHR Δ from Baseline (bpm)

2

1

0

-1

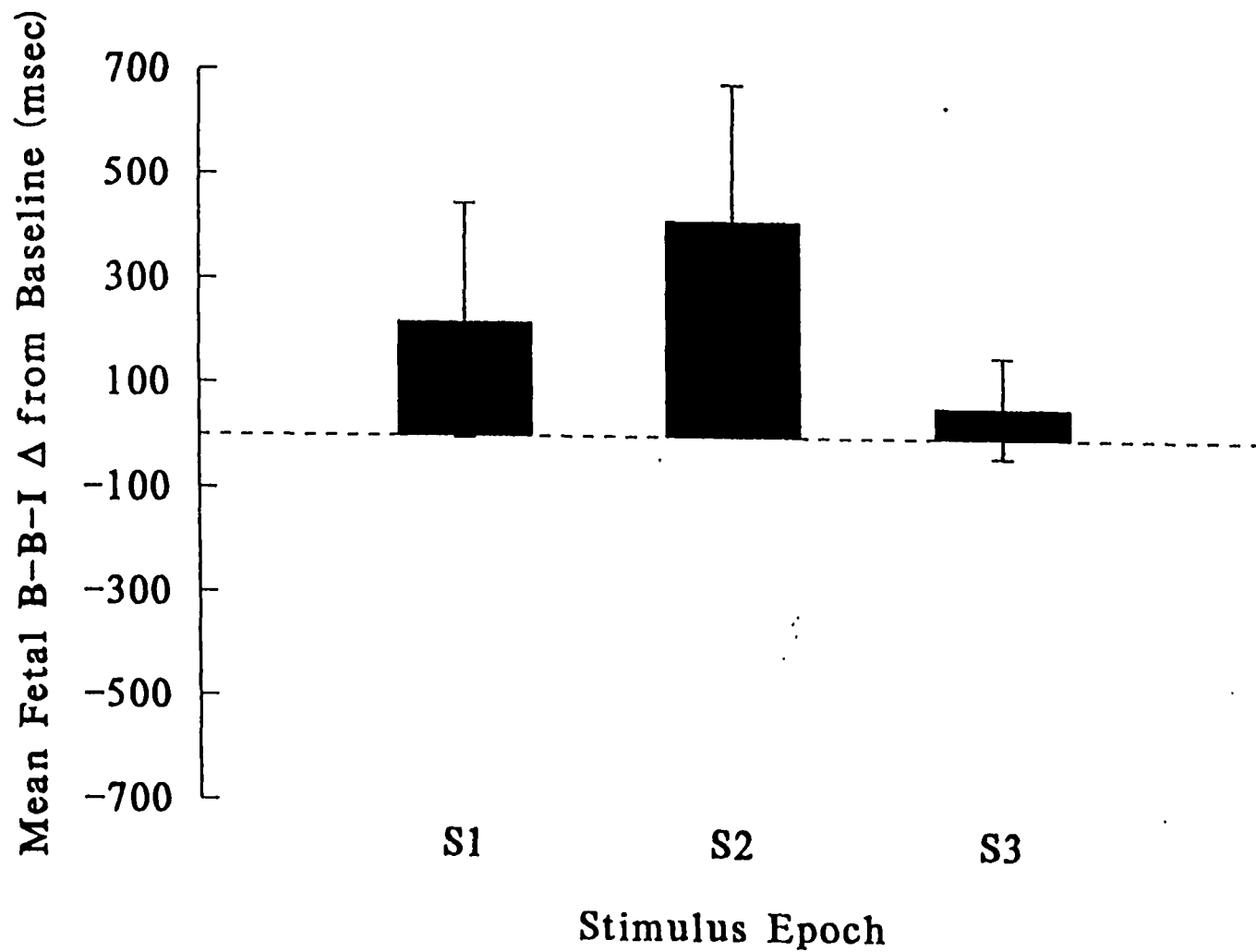
-2

**FIGURE 8**

**Mean changes from baseline in fetal breath-to-breath intervals  
(ms) in three 10s epochs during the labor film**

# Mean Changes in Fetal Breathing With Mother Viewing Labor Film

Figure 8



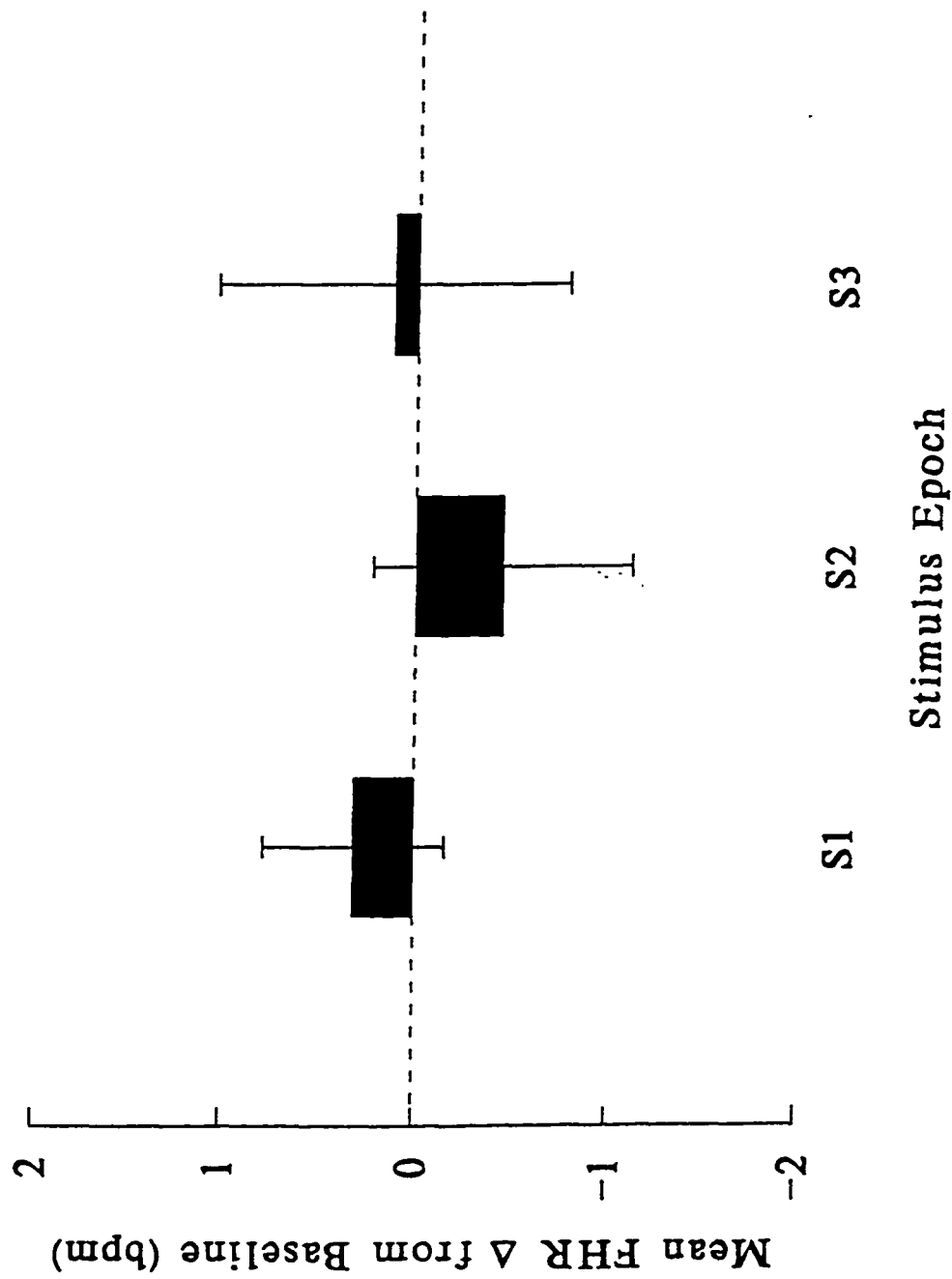
**FIGURE 9**

**Mean changes from baseline in fetal heart rate (bpm) in three 10s epochs during the nature film**

100

# Mean Changes in FHR With Mother Viewing Nature Film

Figure 9



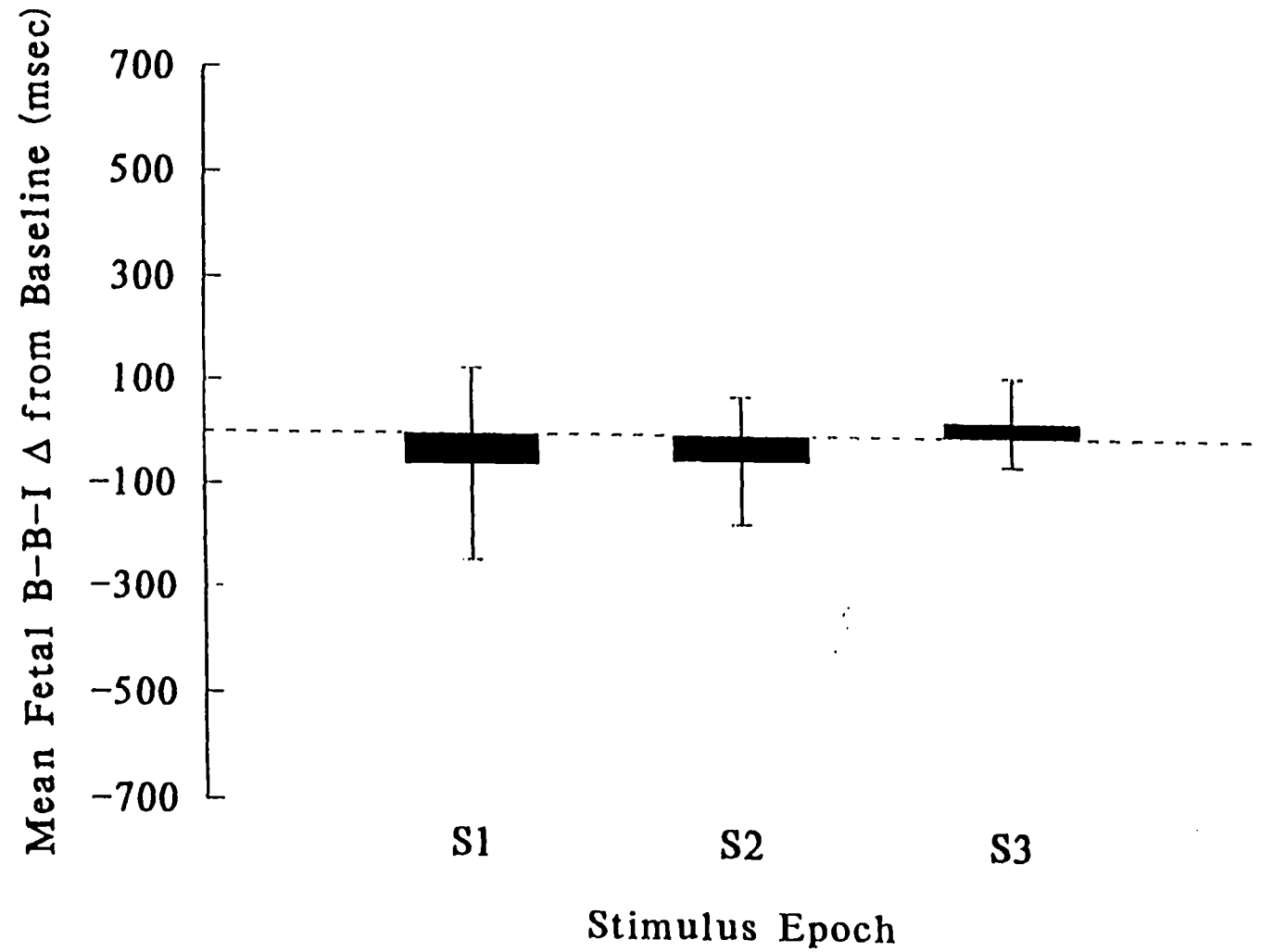
**FIGURE 10**

**Mean changes from baseline in fetal breath-to-breath intervals  
(ms) in three 10s epochs during the nature film**

...

# Mean Changes in Fetal Breathing With Mother Viewing Nature Film

Figure 10

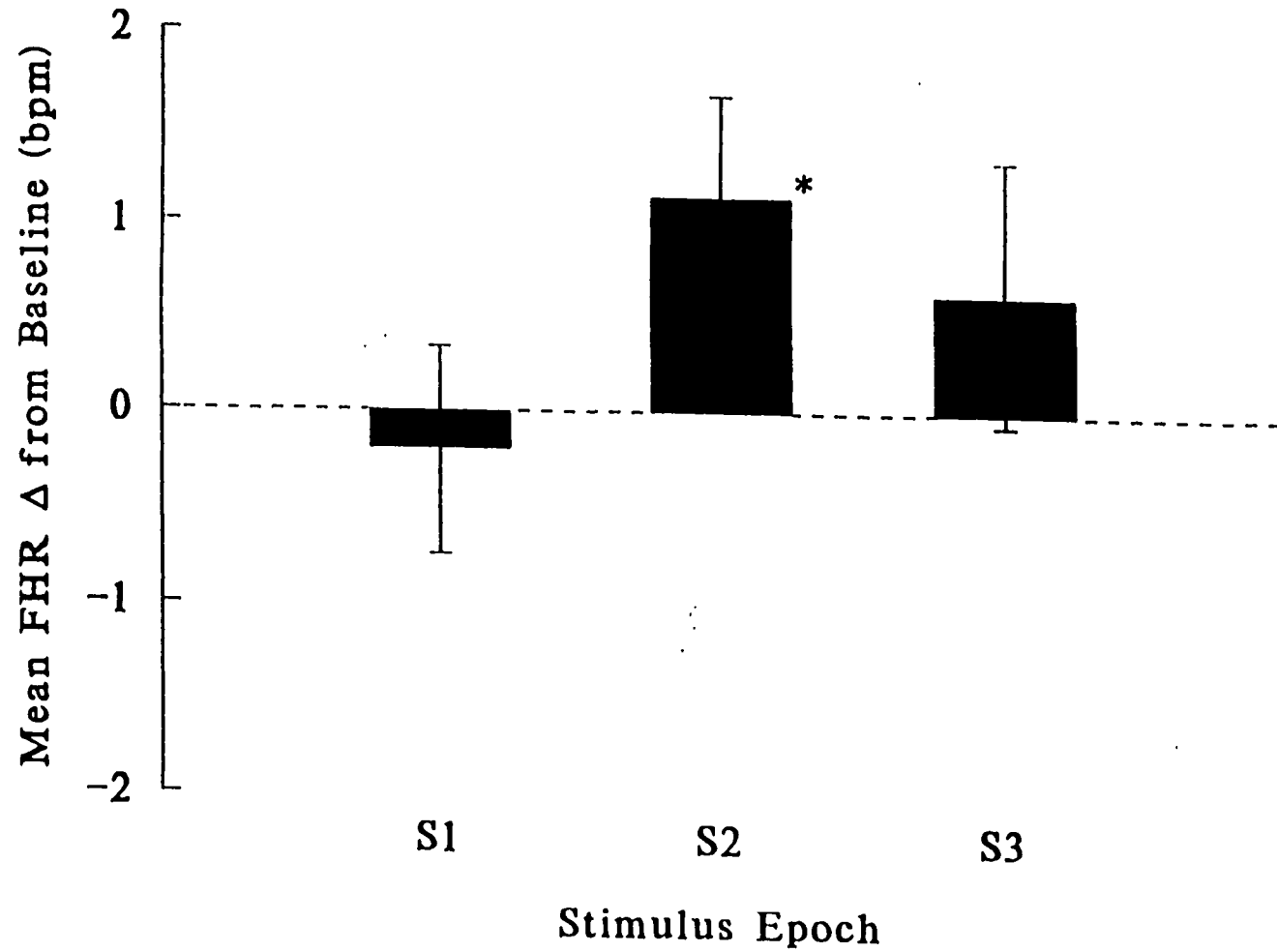


**FIGURE 11**

**Mean changes from baseline in fetal heart rate (bpm) in three 10s epochs during the breastfeeding film.**

# Mean Changes in FHR With Mother Viewing Breastfeeding Film

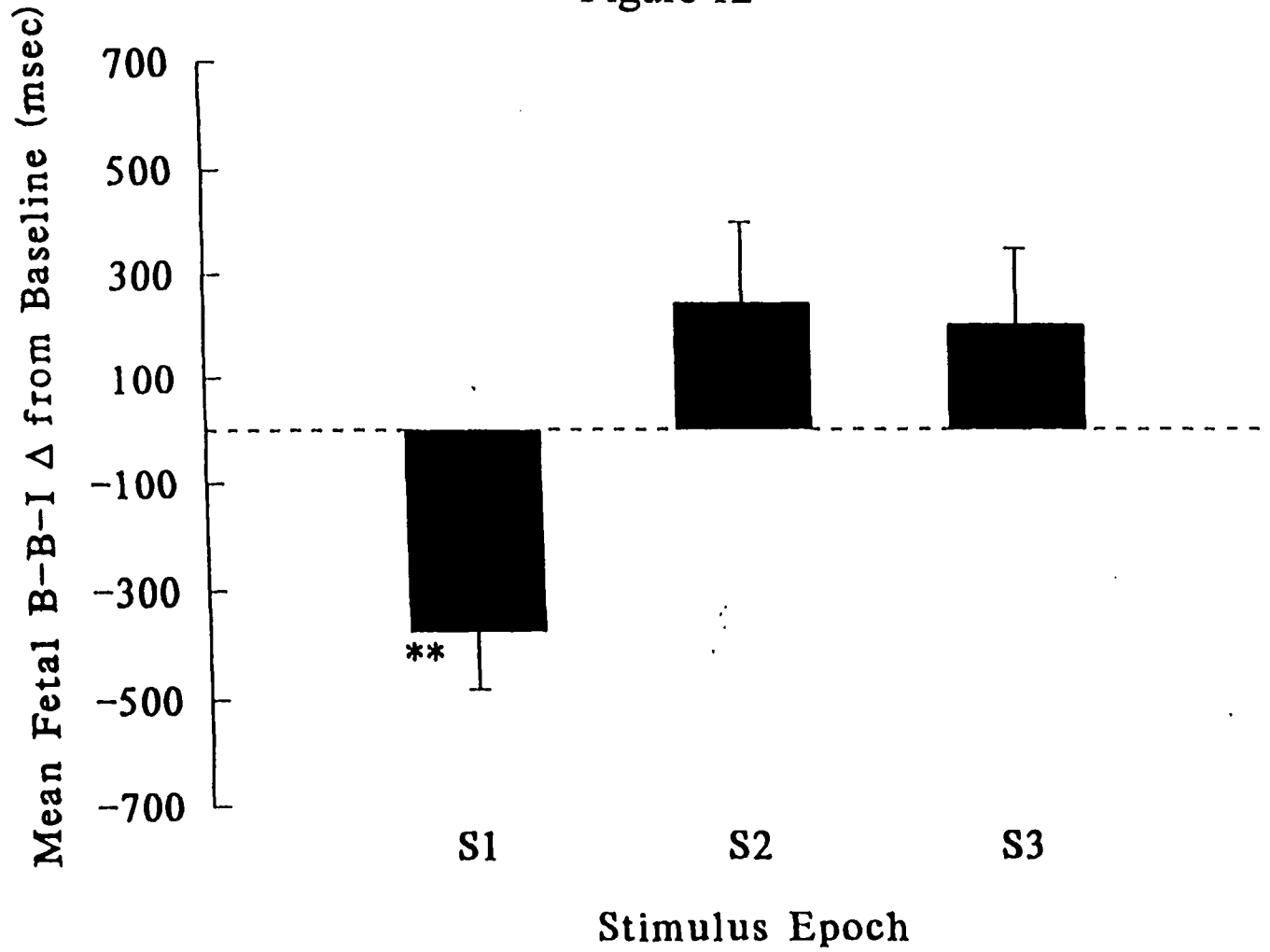
Figure 11



**FIGURE 12**

**Mean changes from baseline in fetal breath-to-breath intervals  
(ms) in three 10s epochs during the breastfeeding film**

Mean Changes in Fetal Breathing With Mother Viewing  
Breastfeeding Film  
Figure 12

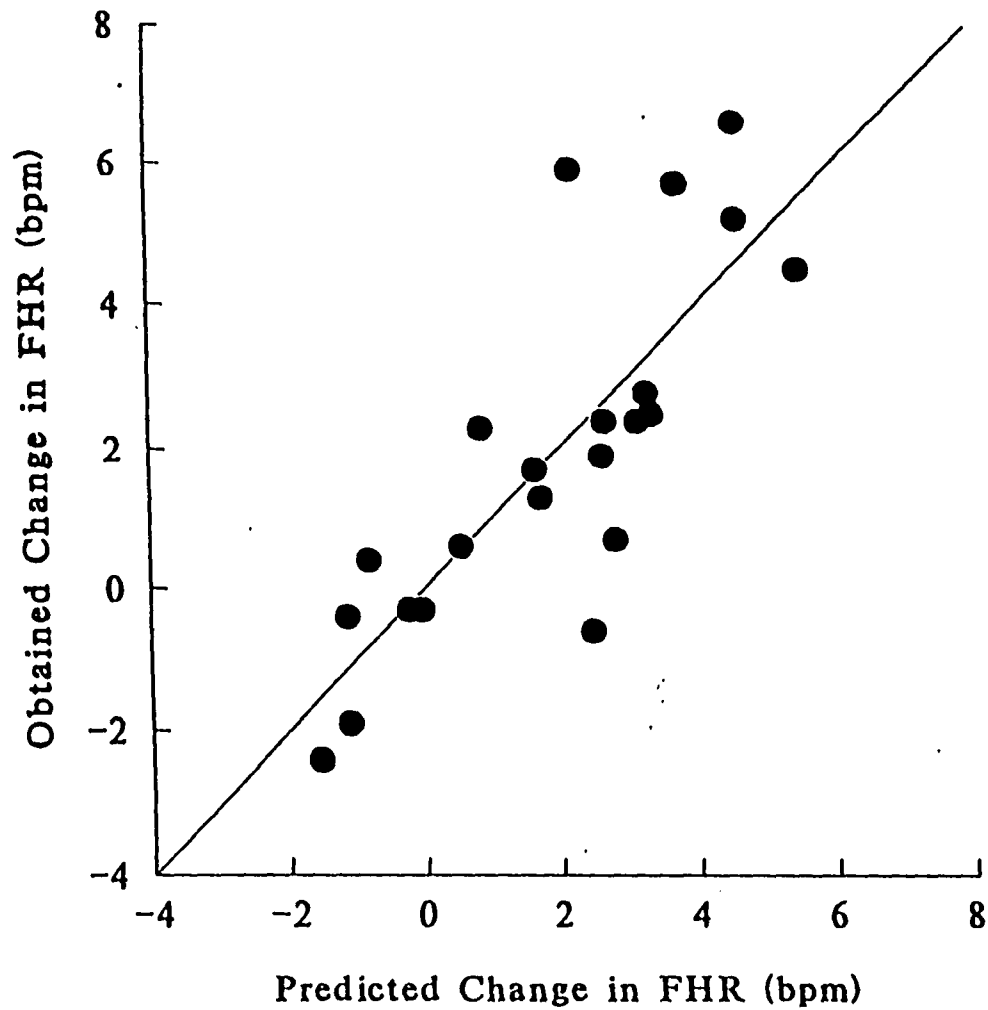


**FIGURE 13**

**Multiple-regression analyses: predicted vs actual changes  
in fetal heart rate using four maternal physiological  
variables**

### Predicted Change in FHR from Maternal Physiological Changes

Figure 13



### **Appendix III**

#### **Columbia-Presbyterian Medical Center Research Protocol**

##### **Study Title: "Effects of Auditory and Visual Stimulation on Mother and Fetus"**

###### **Purpose of study:**

It is our goal to examine the effects of emotionally salient auditory and visual stimulation on maternal and fetal behavior. Emotional states have long been associated with specific autonomic bases. Neural substrates and mechanisms that underlie emotional expressions exhibit differential blood pressure changes in systolic and diastolic pressure in response to emotionally laden stimuli. In a recent study, one day old neonates showed a differential cardiovascular and respiration response to maternal voice stimuli. These results suggest that there is something perceptually salient about the mother's voice as evidenced by the neonate's cardiovascular responses. The question under investigation in this study is to examine the effects of emotionally laden auditory and visual stimulation on both the mother and fetus.

The notion of emotions eliciting physiological responses in a human pregnant female suggests the possibility for cascading consequences in fetal development. The objective in this study is to examine the effects of auditory and visual stimulation on both mother and fetus. Namely, are fetuses sensitive to mother's response to emotionally laden information? If so, then, how is mother's physiological response to emotionally laden information transduced to the

fetus?

**Experimental Design:** It is our hypothesis that fetal behavior (i.e. heart rate, breathing and body movements) will change as a function of maternal physiological responses to emotionally laden stimulation. The effect of induced maternal emotions on fetal behavior has been shown in a study in which near-term pregnant women were shown a film of a normal delivery. The results indicate that changes in maternal emotional state were significantly correlated with the motor activity of the fetus.

Evidence for the effects of emotional auditory influence on both maternal and fetal behavior is noted in a study in which pregnant women listened to recordings of infant crying. Fetal heart rates showed pronounced behavioral responses to increases in maternal heart rate. Infant cries have been shown to be an especially salient auditory emotional stimulus such that psychophysiological responses to infant cries have been used as an index of infant well being. As cries of low birth weight and pre-term infants have a fundamental frequency averaging 1000 to 2000 Hz, as compared with that of normal infants which average 450-600 Hz, studies have shown that the effects of variations in infant cry have consequences for adult responses. This was evidenced in a study in which normal infant cry elicited a moderate heart rate acceleration in adults and aberrant infant cries elicited high heart rate accelerations in some adults. Stimuli such as noises and

frightening events have been shown to have both negative and positive effects. This evidence suggests that maternal physiological states may have behavioral and developmental consequences for the fetus.

Fetal breathing movements have been used as an indicator of fetal well being. The presence of fetal breathing movements is a sign of fetal health and the absence is interpreted as a sign of fetal hypoxia. Clinical significance has been attributed to fetal breathing as an indicator of risk for premature labor. Fetal breathing is episodic and it is difficult to document normal breathing patterns with a reasonable period of time. However, changes in breathing activity during uncomplicated pregnancies can be determined by measurement of fetal breathing related nasal fluid flow velocity.

#### Method

In our study, patients will be monitored in sessions of one hour duration. Maternal monitoring will include, maternal heart rate, blood pressure and respiration. Fetal monitoring will include ultrasound examination of fetal breathing and body movements. Fetal breathing related nasal fluid flow measurements will be monitored by means of color flow and spectral Doppler ultrasound analyses.

**Procedure:**

Following informed consent and agreement from the patient's physician or midwife, as to the patient's ability to participate in this study, patients will be invited to participate in this study. Patients will not be required to have a full bladder to participate. The patient will be asked to relax and remain in a semi-recumbent position throughout the study. The patient will be informed that should they experience any discomfort at any time during the study, they are free to discontinue the study. This procedure will be done in a quiet room located on the 12th floor of the hospital in the ultrasound department.

Easily removed electrodes will be attached to the mother to record both heart rate and respiration. A finger cuff will be attached to monitor blood pressure. Fetal heart rate will be recorded using a transducer on the maternal abdomen. Fetal breathing will be monitored using color Doppler flow measurements obtained by means of an abdominal transducer. There will be two conditions in this study; 1) auditory: infant cry and coo sounds will be presented to the mother over a headset. (Sounds will not exceed 70 dB); 2) visual: a film of a normal delivery will be presented to primigravid patients. This film is currently being used as part of a childbirth class and will not have been viewed by the subjects prior to the study. A standard protocol will include a 10 minute baseline during which both maternal and fetal

physiological variables will be recorded. Following baseline, one of the conditions will be presented in sets of 4 samples per stimuli, each block will be presented within a randomized order to counterbalance any order effects. Presentation of stimuli will proceed as follows: Baseline, stimulus, sham, stimulus.

During the presentation of stimuli, maternal and fetal physiological and behavioral responses will be recorded as indicated.

This procedure will be performed by Yvonne Masakowski, M.A. under the supervision of Dr. I. Timor and Dr. S. Badalian. Ms. Masakowski is a doctoral student at CUNY who has been affiliated with the ultrasound department for approximately 2 years. Ms. Masakowski was trained by Drs. I. Timor and E. Zimmer.

Site of Study: The study will be conducted in the CPMC Division of Ultrasonography, Department of Obstetrics and Gynecology.

Recruitment of Subjects: A pilot study of 10-20 normal, primigravid patients without anomalies will first be performed to establish the technique and to evaluate the sample size needed to answer the outlined questions.

Physicians may refer patients to the investigator. Any patient who presents themselves to the investigator will be

screened for their suitability to participate in this study with their primary medical caregiver prior to acceptance as a participant in this study. Following agreement with the patient's primary physician or midwife as to their acceptability to participate in this study, the investigator will explain the procedure to the patient. Any question will be answered by one of the investigators and if the patient agrees, the consent form will be signed and the patient will be recruited for the study.

**Risks and Potential Benefits:** Ultrasonography is an established modality used in almost all specialties and in obstetrics and gynecology in particular. Sound waves, if used at diagnostic levels and intensities were never implicated in any detrimental effects on patients or fetuses.

The potential benefits of the study are: 1) understanding the effects of maternal physiological changes on fetal well being, 2) prediction of postnatal development

**Alternative Therapies:** not applicable

**Compensation:** No compensation will be provided

**Pediatrics approval:** Not applicable

**Drugs:** Not applicable

### Appendix IV - SUMMARY OF BIRTH STATISTICS

ID	AGE YRS	GA WKS @STUDY	GA WKS @BIRTH	APGAR 5 MIN	APGAR 10 MIN.	BIRTH WT .	SEX
1	20	40	40	9	9	3445 g	M
2	20	37	41	8	8	3635	M
3	31	36	41	8	9	3430	F
4	18	40	42	9	9	3900	M
5	33	38	38	8	9	3310	M
6	22	39	40	9	9	3440	F
7	14	38	40	9	9	3410	M
8	15	39	39	8	9	3150	M
9	17	39	39	8	8	3030	M
10	31	36	39	9	9	3730	M
11	30	37	41	9	9	3175	M
12	27	36	37	8	9	2890	F
13	40	37	40	8	9	3400	M
14	22	36	40	9	9	2670	M
15	27	36	36	9	9	3140	M
16	21	37	40	8	9	4150	M
17	24	37	41	8	9	2863	F
18	16	37	41	8	9	4250	M
19	17	37	38	9	9	3670	M
20	18	38	40	8	8	3440	M
21	15	38	40	8	9	3075	M
22	25	37	38	7	8	3180	M
23	20	36	39	8	9	2863	M
24	34	37	39	8	9	3200	M
25	33	36	41	9	9	3085	M
26	22	36	41	9	9	3365	M
27	18	39	40	8	9	3115	M
28	19	38	40	9	9	3175	M
29	22	36	39	9	10	3250	M
30	17	40	40	9	9	3220	M
31	18	36	41	9	9	2785	M
32	17	36	38	9	9	2805	M
X	23.07	37.3	39.6	8.44	8.86	3317.79	

**Appendix V****Columbia-Presbyterian Medical Center  
Consent Form****Consent to Participate in a Research Study**

The purpose of this consent form is to provide you with the information you need to consider in deciding whether to participate in this research study.

**Study Title: "Effects of Auditory and Visual Stimulation on Mother and Fetus"**

**Study Purpose:** You are invited to participate in a research study to examine the effects of auditory and visual stimulation on mother and fetus. Drs. I. Timore, S. Badalian, W. Fifer and Y. Masakowski, M.A., hope to discover the effects of auditory stimulation on maternal heart rate, blood pressure and respiration and fetal heart rate, respiration and body movements. The hope is to discover if the rate of change of these physiological measurements may help to predict postnatal outcome.

**Study Procedures:** If you decide to participate in this study, you will be examined once for a one hour time period. During this time period, your heart rate, blood pressure and respiration will be monitored. In addition, blood samples may

be drawn by Dr. S. Badalian at both the outset of the study and one time during the study.

Note: This procedure will be performed by Y. Masakowski, a doctoral candidate at CUNY, who has been affiliated with the ultrasound department and has performed research sonography under the supervision of that department for approximately two years. Ms. Masakowski will be technically supervised by Dr. I. Timor and Dr. S. Badalian.

Study Risks: There is no known risk in the ultrasound examination.

Study Benefits: You are not likely to benefit from this study. However, the information from this study could help with the future diagnosis of infants.

Alternatives: The alternative to participating in this study would be to have a routine ultrasound without the additional time for imaging in this study.

Compensation: You would not be charged for any extra time, procedures, imaging processing, etc. involved in this study.

Confidentiality: Any information obtained during this study and identified with you will remain confidential. No reference will be made which can identify any individual in

publications or reports.

Participation is voluntary: Your participation in this study is completely voluntary. You can refuse to participate or withdraw from the study at any time and such a decision will not affect your medical study at any time and such a decision will not affect your medical care at Columbia-Presbyterian Medical Center now or in the future.

Questions: If you have any questions, please ask. In the future, should you have any questions, you can reach Drs. Timor or Baddalian at (212) 305-2169 and Dr. Fifer or Ms. Masakowski at (212) 960-5708. If you have any questions on your rights as a research subject, you can call the Institutional Review Board at (212) 305-5883 for information.

Signature: \_\_\_\_\_/\_\_\_\_\_

Investigator Eliciting Consent/Date

**PLEASE NOTE**

**Materials in this document have not been filmed at the request of the author. They are available for consultation, however, in the author's university library.**

**pages 103-104**

**UMI**

## APPENDIX VII

VIDEO REACTION QUESTIONNAIRE

**Video 1.**            During this film....

I felt calm

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt happy

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt frightened

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt upset

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt pleasant

not at all	somewhat	moderately so	very much so
1	2	3	4

**Video 2.**            During this film...

I felt calm

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt happy

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt frightened

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt upset

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt pleasant

not at all	somewhat	moderately so	very much so
1	2	3	4

**Video 3.**                    During this film....

I felt calm

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt happy

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt frightened

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt upset

not at all	somewhat	moderately so	very much so
1	2	3	4

I felt pleasant

not at all	somewhat	moderately so	very much so
1	2	3	4

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