ADULT SENSORY CAPACITIES
AS A FUNCTION OF BIRTH RISK FACTORS

by

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Abstract

This study examined the relationship between the events surrounding one's birth and subsequent sensory capacity in adulthood. Data was extracted from the Human Neuropsychology and Perception Laboratory Data Bank at the University of British Columbia to determine whether mild birth risk factors have an impact on adult sensory capacities. The final sample consisted of 716 female and 529 male participants (mean age = 19.9) for whom both an indication of birth stress and at least one measure of sensory capacity were available. The extent of birth stress was determined by having subjects complete a questionnaire examining the incidence of nine birth risk factors during their birth: a) long labour b) breech birth c) breathing difficulty d) instrument delivery e) Caesarian delivery f) multiple birth g) premature birth h) low birth weight and i) high risk birth order. Seven sensory capacities were also tested using standard laboratory techniques; these included visual acuity, macular suppression, stereopsis, colour discrimination, pure tone hearing, speech recognition and sound localization.

Significant associations between mild birth stressors and reduced adult capacity were found. Of the birth stressors examined, long labour was found to affect the sensory systems the most, possibly because other birth stressors such as hypoxia and forceps delivery often coincide with prolonged labours. Vision was found to be more vulnerable to birth stress effects than was audition, which may be due to the fact that the visual system matures more slowly than does the auditory system. These results suggest that it may be useful to include sensory factors in the pattern of deficits usually called the Alinormal Syndrome.

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Chapter One: Introduction

The relationship between the events surrounding the perinatal period and the subsequent development of the child was clearly expressed as early as the eighteenth century, when Smellie (1772, in Schwartz, 1961) suggested that the birth process can alter the shape of the head so as to cause cerebral lesions fatal to the newborn. Smellie wrote:

"In lingering labours, when the head of the child hath been in the pelvis, so that the bones ride over one another and the shape is preternaturally lengthened, the brain is frequently compressed, that violent convulsions ensue before or soon after the delivery of the child".

In the nineteenth century, Little (1862) and Freud (1897) wrote on their observations linking cerebral palsy and mental retardation to the events of birth. In the late twentieth century, while the infant mortality rate has fallen in the past century due partially to the wide-spread introduction of neonatal intensive care units, the morbidity rate remains constant, and a substantial number of infants are still born suffering from major and minor physical and psychological impairments.

Since fetal development must occur by orderly differentiation of each organ system to a state of maturity compatible with extrauterine life, anything interfering with this process may lead to developmental problems of the neonate. Similarly, adverse events during labour, whether occurring prematurely or at term, have some potential for creating fetal injury resulting in long-term neurological and functional handicap (Wigglesworth, 1984). Trauma to the fetus during the prenatal and perinatal periods

may result in major neurological impairment such as blindness, deafness, cerebral palsy, epilepsy, or severe mental retardation (Hunt, Tooley & Harvin, 1982; McKay, 1967). In addition, less severe birth stress may result in more moderate physical, cognitive, or behavioural impairments (Pasamanick & Lilienfeld, 1955) which may not be immediately apparent.

Research concerning the implications of birth trauma on the neuropsychological and behavioural development of infants is now being conducted in an attempt to understand and prevent infant impairment. Over the past 30 years, numerous studies have been carried out to determine whether infants experiencing birth complications differ in subtle ways from their normal peers. Many of these studies have followed their subjects into middle childhood in an effort to determine the permanence of the deficiencies as well as the relative contributions of genetic and environmental factors. Through these investigations, numerous variables have been identified as factors that may contribute to less than optimal fetal and neonate development; these may be categorized as risk factors exhibited prior to pregnancy, during pregnancy, or during labour and delivery (Gray & Dean, 1991).

Risk Factors Exhibited Prior to Pregnancy

One of the most salient risk factors prior to pregnancy is the age of the mother at the time of conception, with both younger and older mothers being at risk for problem pregnancies. Adolescent mothers (aged 17 years or less) have been shown to have a higher than normal incidence of premature deliveries, stillbirths, and neonatal mortality (Dwyer, 1974; Niswander & Gordon, 1972), and their offspring tend to manifest

intellectual and motor development delays (Broman, 1978). Older mothers (over 35 years of age) tend to experience significantly more breech deliveries, premature births, and they also give birth to more neonates with congenital abnormalities (Kajanoja & Widholm, 1978). In general, older mothers experience twice as many labour abnormalities as younger mothers (Cohen, Newman & Friedman, 1980).

Another important prepregnancy variable is the mother's previous reproductive history. Reproductive events such as a history of premature births and previous fetal death tend to be good predictors of perinatal complications in future pregnancies. Similarly, a history of elective abortions also predicts future complications, as cervical injuries and intrauterine scarring resulting from the abortions may place subsequent fetuses at risk for prematurity and intrauterine growth retardation (Hobel, 1985).

Birth order is also an important factor since greater morbidity and mortality of neonates is associated with first pregnancies. Risk increases as well for pregnancies beyond the third (Bakketeig & Hoffman, 1979; Dowding, 1981). While maternal age is confounded with later pregnancies, infant birth order should none the less be considered to be indicative of possible birth complications.

The socioeconomic status of the mother has also been implicated in pregnancy complications, partly due to the fact that mothers of low socioeconomic status are more likely to have histories of cigarette smoking, insufficient weight gain during pregnancy, and general poor prenatal care (Miller, Hassanein & Hensleigh, 1978). As a result, mothers of low socioeconomic status tend to experience significantly more premature deliveries than the general population (Berkowitz, 1981). These perinatal factors

associated with low socio-economic status have been implicated in developmental disabilities, cerebral palsy, seizure disorders as well as learning disabilities (Avery, 1985; Caputo, Goldstein & Taub, 1981).

Risk Factors Exhibited During Pregnancy

Fetal development is naturally influenced by the maternal-placental environment, and therefore any chemicals that are ingested during pregnancy may have a negative effect on normal fetal development. As is commonly held, maternal smoking during pregnancy is associated with delayed development in both intrauterine and extrauterine environments. Specifically, significant links have been found between smoking and retarded intrauterine development and the associated low birth weight (Avery, 1985; Butler, Goldstein & Ross, 1972), children's cognitive development on measures of reading comprehension, mathematics and general ability (Butler & Goldstein, 1973; Butler, Goldstein & Ross, 1972), as well as deficits in infants' auditory discrimination (Saxton, 1978).

Alcohol has also been tagged as having detrimental effects on developing fetuses. Numerous studies have found a significantly greater than normal incidence of mental retardation, growth retardation, hyperactivity, speech difficulties, and microcephaly among the offspring of alcoholic mothers (Hanson, Jones & Smith, 1976; Iosub, Fuchs & Bingol, 1981; Jones & Smith, 1975). Even moderate social drinking during pregnancy may adversely affect the developing fetus; Hanson (1977) found that the offspring of mothers who consumed alcohol moderately during pregnancy were five times more likely to experience growth problems and microcephaly than those whose mothers abstained

from drinking during pregnancy.

Psychosocial stress and the physiological changes that accompany stress have also been found to influence the outcome of pregnancies. High levels of maternal stress have been found to be associated with increased risk of delivering infants with low birth weight or physical disabilities (Newton, Webster & Binu, 1979) as well as increased risk of childhood neurological, developmental and behavioural disorders (Stott, 1973). Newton et al. (1979) also found a direct relationship between the degree of maternal psychosocial stress as measured by the Life Events Inventory (Cochrane & Robertson, 1973; examples of major life stressors include divorce, death of an immediate family member, getting into debt beyond the means of repayment etc.) and the degree of prematurity of the delivery, such that the more stress the mother experienced, the greater the degree of prematurity.

Another important variable associated with the prenatal period is the magnitude of maternal weight gain during pregnancy. Generally speaking, the data suggest a linear relationship between maternal weight gain and birth weight, such that increased maternal weight gain seems to improve infant birth weight and also seems to decrease the chances for infant mortality (Niswander, Singer & Westphal, 1969; Simpson, Lawless & Mitchell, 1975). The total weight gain recommended for women of normal weight is 25 to 35 pounds, underweight women may gain up to 40 pounds, and overweight women should limit their weight gain to 25 pounds (Gabbe, Niebyl & Simpson, 1991).

Risk Factors Exhibited During Labour and Delivery

Although it is unquestionably possible to harm the fetus through the physical

stress associated with the natural mechanics of delivery, at present day, this occurs with surprising infrequency (Lee, 1987). At present, perinatal neurological morbidity tends to be associated with labour abnormalities and complications, rather than the normal birthing process.

The single greatest cause of perinatal mortality is breech presentation of the neonate at delivery (De Crespigny & Pepperrell, 1979), a fact that is well known by both laypeople and professionals alike. While breech presentation is associated with abnormal events surrounding the birth such as greater incidence of prematurity (Kauppila, 1975), birth anoxia (Jurado & Miller, 1968; Wheeler & Greene, 1975) and cord prolapse (Alexopoulos, 1973), it is also associated with long-term neurological disorders. Churchill & Colfelt (1963), for example, found that breech deliveries were more likely to result in cerebral palsy or epilepsy than were spontaneous vertex deliveries. In addition, Muller et al. (1971) found that children born in the breech position experienced significantly more cognitive and learning difficulties that required treatment. These deficits may result from potential oxygen deprivation or neurological insults that may be concomitant with abnormal presentation.

The use of forceps for deliveries has long been identified as a major factor in birth trauma and the subsequent neurological sequelae (Eastman, Kohl, Maisel & Kavalier, 1962; Friedman, 1987; O'Driscoll, Meagher, MacDonald & Geaghegan, 1981). In fact, autopsies of neonates dying during or following difficult deliveries have shown traumatic lesions resulting from forceps use including neonatal skull fractures, subdural haematomas and tentorial tears (Towbin, 1970). While the use of forceps has drastically

decreased in the past decade, they are still used in many difficult deliveries such as breech presentation, but not without controversy. Both proponents (Friedman, 1987) and opponents (Hayashi, 1987) agree that the issue of mid-cavity forceps' impact on the newborn can only be settled by a well-controlled prospective study. However, for moral, medical and legal constraints, such a study will probably never be carried out. None the less, whether forceps themselves cause irreparable damage to the newborn, or whether the use of forceps is but a marker for complications that have already arisen, the identification of their use is important in determining the extent of birth difficulty.

Oxygen deprivation during the perinatal period (perinatal hypoxia) can also result in death or neurological abnormalities (Fitzhardinge & Pape, 1981), with cerebral palsy and encephalopathy often the outcome (Freeman, 1985; Low, Galbraith, Muir, Killen, Patar & Karchmar, 1985). Low et al. (1985) found that 66% of the cases of severe encephalopathy could be attributed to perinatal hypoxia. Similarly, Low, Galbraith, Muir, Killen, Patar & Parchman (1984) reported that over 50% of the children with a history of prolonged hypoxia experienced cognitive and motor deficits.

Another frequently cited perinatal risk factor is low birth weight. Although a steady improvement in the survival rate of low birth weight neonates (< 2500 g) and very low birth weight neonates (< 1500 g) has been observed, the morbidity rate for neurodevelopmental disorders remains high when compared to normal birth weight infants. Low birth weight has been implicated in mental retardation, cerebral palsy and seizure disorders (Avery, 1985), as well as neurological deficits, learning difficulties and electroencephalogram abnormalities (Fitzhardinge & Steven, 1972). Developmental

delays have also been found in physical, motor and language development, and mathematics ability (Caputo & Mandell, 1970; Lee & Barratt, 1993).

Closely related to the concept of birth weight, gestational age is also considered to be an important risk factor. Neonates born prematurely (before the 38th week) are also at risk for a number of cognitive and neurodevelopmental disorders (Caputo, Goldstein & Taub, 1981; Commey & Fitzhardinge, 1979). For example, Caputo et al. (1981) found that children aged 7 to 9 who were delivered prematurely scored significantly lower on the Wechsler Intelligence Scale for Children-Revised, and also showed significant impairment on subtests involving visual-spatial processing.

The speed of delivery of the neonate is also of concern, as both labours that are too long or too short tend to be associated with more complications than those of moderate length (Rosenblith, 1992). In precipitate deliveries (where second stage labour lasts less than 10 minutes) contractions may be too close together to provide adequate oxygen for the fetus. Additionally, the head may be subjected to such pressure that blood vessels in the brain hemorrhage, causing injury to the brain. Prolonged labour can also be hazardous, as anoxia may be caused by long-term squeezing of the umbilical cord during delivery, or by a decrease in the maternal blood pressure.

While deliveries by Caesarian section were once considered extremely dangerous and performed only upon the death of the mother to save the fetus, they are now extremely popular, and are used in one quarter of the deliveries in the United States (Flamm, 1990). Despite the fact that the maternal death rate is very small today, the chances that the mother may die during surgery are 30% higher than the chances of

women delivering vaginally. While the effects of Caesarian section on the mother are well understood, it is still unclear whether the surgery itself is harmful to the fetus, as it is difficult to disentangle the effects of the Caesarian section from those precipitating the surgery or from the effects of the anaesthetic used. It has been found, however, that neonates delivered by Caesarian section are more likely to develop acute respiratory distress in the immediate postnatal period (Nielsen & Hokegard, 1984). As Caesarian sections are only performed when doctors feel that natural delivery through the birth canal is too risky, birth by Caesarian section may also be considered to be a marker for birth abnormalities.

Multiple pregnancy has also been associated with poorer neonatal outcome, precipitating preterm labour and contributing significantly to the number of extremely low birth weight babies (under 1000 g) admitted to special baby care units. In a recent review of pregnancies ended between 20 and 28 weeks of gestation, Harvey, Cooke and Levitt (1989) found that 16% of the infants were twins, a significantly larger proportion than that found in the population of full-term infants.

Sensory Deficits

In addition to the cognitive, motor and behavioural deficits that birth stressed children tend to exhibit in infancy and childhood, numerous studies have shown a greater incidence of sensory deficits, particularly major visual and auditory deficits, among perinatally compromised infants (Caputo & Mandell, 1970; Friedman, Jacobs & Werthman, 1981). Visual and auditory impairments among premature and low birth weight infants are not surprising when one considers how underdeveloped and

unprepared their auditory and visual systems are for the extrauterine world. While all sensory systems begin to mature before birth, they do not all mature at the same rate, nor are all systems fully functioning at birth (Bradley & Mistretta, 1975). It is possible that the neonate's ability to take advantage of environmental stimulation may be hampered by an immature sensory system; furthermore, it is also possible that environmental stimulation may actually be damaging to the sensory systems that have not completed maturation.

The development and refinement of methods of measuring sensory processing in young infants have permitted comparative studies of the sensory capacities of preterm and term neonates to be conducted. In general, these studies have yielded evidence for sensory deficits in preterm babies. For example, in examining auditory responses, Katona and Berenyi (1974) found deficits in newborn preterms' behavioral responsiveness to sound when the gestational age of the infants was less than 29 weeks. Along the same lines, Eisenberg, Coursin, and Rupp (1966) found that eight full-term neonates were quicker to habituate to a repeatedly presented modulated tone than were two preterms. Field, Dempsey, Hatch, Ting & Clifton (1979), however, did not find deficits in the behavioural responsiveness of preterm infants of 37.4 weeks conceptional age, but did find that the cardiac responsiveness of the preterms did not significantly decrease when the infants were presented repeatedly with rattle or buzzer noises. More recently, Friedman, Jacobs & Wethmann (1981) found that fullterm infants were somewhat more responsive to auditory stimuli and took longer to reach their auditory response decrement criteria than did preterms. As a whole, the above studies suggest

that preterms who are of younger conceptional ages than fullterm neonates are less responsive to auditory stimulation than the fullterm neonates, and thus demonstrate auditory deficits.

Studies comparing the visual capacities of preterm and fullterm infants do not, unfortunately, yield such consistent data. Katona & Berenyi (1974) presented neonates with rhythmical visual stimuli and found that preterms of less than 29 weeks gestational age gave fewer motor responses (startles) than fullterm neonates. In comparing fullterm and preterm subjects at 5 and 10 weeks after birth, Fantz & Fagan (1975) found that the preterms subjects' duration of attention was significantly shorter than that of fullterms; these differences, however, disappeared when the infants were matched on conceptional age. A study by Petterson, Yonas & Fisch (1980) revealed that 10-week old preterms blinked on significantly fewer trials than did 10-week old fullterms, thus suggesting greater immaturity. Sigman, Kopp, Littman & Parmalee (1977) also found differences in visual processing when fullterm neonates and preterm neonates at expected date of birth were tested, with the preterm infants looking for significantly longer periods of time than did the control subjects. Sigman & Parmalee (1974) found that fullterms but not preterms corrected for conceptional age preferred a novel over a familiar stimulus; however, they showed no differences in the preferences for specific visual stimuli. Friedman, Jacobs & Werthmann (1981), in testing fullterm and preterm infants matched for conceptional age, found that the fullterms were quicker to respond to the stimuli (therefore showing greater development) and also took less time to reach the visual response decrement criteria. In general, in the first year following their birth, preterms

are likely to respond less maturely than term infants. This deficit, however, does not appear consistently in all studies, across all ages, or on all visual measures tested.

While deficits in processing have been found in both the auditory and visual capacities, it is of interest to investigate whether the two senses are equally affected by early developmental interruptions. Gottlieb (1971) has determined that the first sense to develop is the tactile sense, followed by the vestibular, auditory, then visual senses, in sequence. As such, the auditory and visual systems are both relatively slow to develop, and could be susceptible to alterations in the normal developmental progression if they are exposed either prematurely to the outside environment, or to disruptive forces during labour. Furthermore, while the auditory structures are morphologically complete and capable of responding to sound by the end of the sixth prenatal month, the visual modality matures even later in gestation, with the retina not fully developed even at fullterm birth. As such, the visual system could be even more susceptible than the auditory system to disruptions in its development (Campbell, 1985).

In order to determine whether the tactile, auditory and visual capacities were differentially affected by premature exposure to the environment, Friedman, Jacobs & Werthman (1981) developed a procedure which allowed all three senses to be tested in the same environment, and therefore permitted cross-modality comparisons to be made. Results of the study suggested a direct relationship between sensory deficits found in the preterms and the developmental sequence of those sensory abilities in the fetus, such that early developing senses were less affected by prematurity than were late developing senses. While no differences between preterms and fullterms were found on tactile

ability, preterms were found to take significantly more time to reach the response decrement criterion during the auditory task. In addition, during the visual task, not only did preterms take longer to reach the response decrement criterion, they were also significantly slower in responding to the visual stimulus. The authors concluded that sensory modalities that are not mature at the time of birth (i.e. the visual modality) might be more susceptible to damage from extrauterine experience than those that are well developed at birth.

In another study which allowed cross-modality comparisons to be made, Schulte (1977) compared the visual and auditory event related potentials of fullterm infants and prematures matched for conceptional age. In support of the Friedman et al. (1981) conclusion, Schulte found that infants who spent at least three weeks in an incubator demonstrated delayed maturation of the visual event related potential while no differential maturation between groups was found on the auditory event related potential. The author concluded that the visual system may be more vulnerable to the extrauterine environment than the more mature auditory pathways.

Long-term follow-up studies of the cognitive functioning delays in birth risk children suggest a catch-up period, where children exhibit a self-righting tendency so that eventually environmental influences may overshadow biological influences (e.g. Lee & Barrack, 1993). However, no such catch-up period has been documented with sensory deficits, despite the fact that prospective studies have followed children for as long as ten years after birth. These studies consistently report significantly higher rates of visual impairments such as myopia and strabismus among very low birth weight children and

premature children than among average birth weight children, with deficit incidences ranging from 37% to 60% (Dann, Levine & New, 1961; Drillien, 1961; Herrgard, Luoma, Tuppurainen, Karjalainen & Martikainen, 1993; Lubchenco, Horner, Reed, Hix, Ivan, Metcalf, Cohig, Elliott and Bourg, 1963; Rickards, Ford, Kitchen, Doyle, Lissenden & Kieth, 1987). Significant hearing impairments such as sensorineural hearing loss have also been reported among school-aged children born preterm or of low birth weight, with morbidity rates ranging from 8 - 12%. (Drillien, 1961; Herrgard, Luoma, Tuppurainen, Karjalainen & Martikainen, 1993; Stewart, Costello, Hamilton, Baudin, Townsend, Bradford & Reynolds, 1989).

Rationale for the present study

It is obviously of interest to determine whether the sensory deficits noted in children remain through adulthood, or whether a catch-up phenomenon similar to the one seen with cognitive deficits is evidenced at a later date for sensory capacities. Unfortunately, no studies have yet followed birth-stressed individuals beyond the age of ten. The study that follows addresses this issue by testing both birth stressed and non-birth stressed adults for visual acuity and hearing sensitivity, and in addition, extends the laboratory testing to include several additional visual and auditory capacities. This extended set of measures may provide a more complete picture of the relationship between birth stress and sensory deficits. By systematically testing individuals within the same sample on both visual and auditory capacities, the issue of the relative vulnerabilities of the sensory systems at birth can also be examined. It is predicted that the prevalence rates of sensory deficits will differ amongst birth stressed and non-birth

stressed adults, showing a similar pattern to that found previously for children.

Specifically, it is predicted that significantly more visual and auditory impairments will be found within the birth stressed group, and furthermore, that relatively more individuals will show visual rather than auditory deficits. This latter prediction is based upon the slower rate of maturation of the visual system, which extends its period of vulnerability to birth risk factors.

Chapter Two: Data Source and Methodology

The Human Neuropsychology Archival Data Bank

In order to test the relationship between birth stressors and sensory abilities, a large sample of subjects, who have been tested for various sensory capacities and for whom birth history information is available, is needed. Because birth stressors are relatively infrequent, a sample in the range of one thousand or more participants would be desirable. Fortunately, the opportunity to acquire such data exists in an accessible data bank. Records from over five thousand subjects may be retrieved from the Human Neuropsychology Archival Data Bank of the University of British Columbia. This data bank represents fourteen years of data acquisition on a variety of questions but which has often included sensory measures and aspects of medical history including the presence or absence of birth stressors.

All data that have been amassed over the past decade and a half in the Human Neuropsychology and Perception Laboratory, regardless of whether they were collected by questionnaire or systematic laboratory testing, have been stored on disk, using a standard coding system. Full archival records are kept allowing the complete recovery of these data entries. Due to the nature of the coding system, all data records for any one individual share a common entry procedure and subject identification number. This procedure not only allows access to a very large (and always growing) number of subjects, but also permits the study of the interactions between the many collected variables in combinations that they were not originally intended to explore.

One branch of the archival data bank includes data collected on a variety of

aspects of clinical neuropsychology. Targeted questions have included handedness and other aspects of laterality, sleep functions, the extent of birth stress encountered during delivery, as well as general health (see Coren, 1992). In studies carried out over the same time period as the collection of neuropsychological data, subjects were systematically tested on visual and auditory function for the purpose of developing a series of non-invasive sensory screening questionnaires (Coren & Hakstian, 1988, 1989, 1992). Although the neuropsychology data collection and sensory questionnaire projects were conducted quite independently, a large number of subjects participated in both projects. Thus, through extensive extraction, collation and recoding of data files, it was possible to recover more than 1000 subjects for whom both laboratory sensory tests and birth stress information were available. With such a large number of subjects, it was possible to test the hypothesis that perinatal events have an impact on later sensory function without having to return subjects to the laboratory or having to reinvest thousands of hours on the collection of sensory data.

Method

Subjects

Participants included both undergraduate university students and members of the local community who volunteered between 1984 and 1994 for the original general neuropsychological data collection and at least one set of sensory tests. The data search was limited to those data sets in which there was a likelihood that both birth history and sensory testing data on at least one aspect of visual or auditory capacity were available. The majority of subjects were students born between 1964 and 1974 who participated in

these studies as part of an undergraduate subject pool and received partial credit for participating.

Data was discarded if subjects were older than thirty in order to ensure all subjects were born after the wide-spread introduction of neo-natal intensive care units and thus received comparable treatment during their births. Data was also discarded if subjects were under the age of seventeen, as we were interested in looking at adult sensory capacities. Although intelligence and socio-economic status were not examined specifically in this study and could potentially confound the results, it was felt that the university population was homogeneous enough on these two aspects not to necessitate partialling out the variance associated with them. Similarly, although an extended period of time separated the testing of the first and last subjects, it was felt that the ten year span was not long enough or eventful enough to allow confounding variables to muddy the data.

Since we were interested in investigating minor sensory capacity impairments within a normal population, all subjects were required to have adequate sensory capacity to function in the general environment. Individuals with large, debilitating sensory deficits, operationally defined here as those requiring either registration with the university's special assistance program or the provincial sensory handicapped registry or special assistance in the form of visual guide or hearing assistance dogs or the attendance of special aides in the classroom setting were normally excluded at the time of original testing, as were individuals who required the assistance of a hearing aid. Thus all subjects in the present study had adequate sensory capacity to function in the general

social and academic environment, with only the assistance of glasses or contact lenses at the most. The final sample consisted of 1245 subjects (716 females and 529 males) with a mean age of 19.9 years (minimum age=17, maximum age=30).

Measures

Birth stress. While it would have been optimal to determine the extent of birth stress from hospital records or from maternal report, an indication of the proband's knowledge of the events surrounding his own birth was already available within the archival data bank, and was therefore used in the analyses. While this information may be leaner than that obtainable from more direct sources, it was still expected to draw out the presence or absence of the major perinatal events that we were interested in. Mothers often tell their children about the difficulty of their births, how they were a blue baby, how they were in the Intensive Care Unit for weeks, or how she now has an unsightly Caesarian section scar from their birth, and as such, the probands should have a reasonable idea of any difficult events surrounding their births. A recent study carried out by Segalowitz (1993) found an 80% concordance rate between maternal report of birth stress and child's report of birth stress, and therefore it was expected that the birth stress as indicated by the child would be similar to that which would be recalled by the mother, and therefore reliable enough for our purposes.

The extent of perinatal birth stress available within the archival source was collected by having subjects respond on paper to the following questions: "For the following questions, please circle Y for 'yes' and N for 'no'. To the best of your knowledge, was your birth associated with any of the following conditions?"

- a) prolonged labour
- b) breech birth
- c) breathing difficulty or "blue baby"
- d) instrument delivery
- e) Caesarean delivery
- f) multiple birth (eg. were you one of twins or triplets)
- g) premature birth
- h) low birth weight (less than 6 lbs.)

In addition to these birth risk factors, the number of older siblings the subject had was also recorded, and therefore an indication of birth order was present in the data bank. Birth order was considered to be a marker for birth complications if the subject was the first, fifth or sixth child born into the family.

Although false negatives may have occurred because of lack of knowledge, it is unlikely that many false positives would have arisen, as subjects were given the option of leaving a question blank if they were uncertain. Thus, any differences found between the birth stressed and non-birth stressed groups should be conservative in their bias.

Sensory capacity. Four measures of visual capacity and three measures of auditory capacity within the data bank had a sufficient enough sample size for analyses to be conducted. The measures of visual capacity included snellen acuity measured monocularly at both near and far points, macular suppression, stereopsis measured at both near and far points, and colour discrimination. For audition, measurements of pure-tone hearing threshold, speech recognition threshold and sound localization

provided adequate sample sizes for analyses. Sensory abilities were tested using standard laboratory procedures.

Uncorrected visual acuity was objectively assessed with an ophthalmic telebinocular system, using Snellen optotypes which covered the range from 20/10 to 20/200. Assessment was performed under both near and far testing conditions (2.5 and 0.25 dioptries of accommodation, respectively) for the right and left eye separately, at each distance. A composite score, snellen average, was computed as the mean of the near and far measures for the two eyes combined.

Macular suppression, the tendency of one eye to suppress the information coming from the other eye under competitive situations, was tested binocularly with an ophthalmic telebinocular system at both the near and far points. Scores range from 20/20 to 20/200, with scores of 20/30 or below being expected. A composite score, macular suppression average, was computed as the mean of the near and far measures.

Stereopsis, a measurement of the ability to judge varying distances by means of binocular disparity, was tested binocularly at both near and far points. The last line correctly identified on the chart was recorded. The stereopsis average was computed as the mean of the near and far measures.

Colour discrimination was assessed using the Farnsworth-Munsell 100-Hue Test (1957), administered under a correlated source C illuminant with an intensity of 310 lx. This test separates people with normal colour vision into classes of superior, average and low colour discrimination, and also measures the zones of colour confusion in colour defective people. In this task, subjects are asked to arrange coloured caps in order so

that they form a regular colour series between two fixed caps. Total error scores are obtained by summing the differences of the numbers on the adjacent caps, so that larger transpositions result in larger error scores.

Pure-tone hearing threshold was assessed using a MAICO (MA-24) audiometer in a sound-deadened room. Pure-tone air-conduction hearing thresholds were obtained for test frequencies of 500,1000,2000 and 4000 Hz. Each ear was tested separately, using an initial descending sequence of 10-dB steps, followed by three ascending sequences with 5-dB steps (Hodgson, 1980). The median of the three ascending measures served as an estimate of threshold sensitivity for that ear. The composite pure-tone threshold average was computed as the mean of the thresholds at all frequencies.

Speech recognition threshold was also assessed using the MAICO audiometer in a sound-deadened room. The stimuli used were the CID W-1 tests (tapes E and F) for spondees. The starting point for this test was set at 30 dB above the determined pure tone threshold for 1000 Hz. Each ear was tested separately, using an initial descending sequence of 5-dB until two words were missed, followed by five descending sequences with 5-dB step. The threshold was calculated as the last level in which all recognitions were correct, corrected downward for the percentage correct responses for levels in which reports were only partially correct following the procedures recommended by Hodgson (1980). The speech recognition average was calculated as the mean of the thresholds for each ear.

Sound localization was tested by having subjects identify where sounds originated. Subjects sat with head immobilized facing a felt screen located 10 feet in front of them.

Nine speakers were hidden behind the screen. One speaker was located at the subjects' midline and one each at 10, 25, 35 and 45 degrees to the left and right. A scale consisting of coloured letters ran horizontally across the full width of the screen. Letters were spaced at 1 degree intervals. Subjects were told that sounds would come from behind the screen and that they were to call out the colour and name of the letter closest to the sound's location. Stimuli were 1000 Hz tones, each approximately 0.75 seconds in length, each presented twice in mixed order. Scores were coded as the difference in number of degrees of arc between the actual and guessed locations.

Chapter Three: Results

Subjects were classified as non-birth stressed individuals if the birth risk item in question was not checked on the questionnaire, or birth stressed individuals, if the birth stressor being addressed was indicated as having occurred during their delivery. An additional birth stress variable, birth order, was derived and included in the analyses. For this measure, individuals who were the second, third or fourth child in the family were considered non-birth stressed, while those born first, fifth, or sixth etc. were considered to be birth stressed. Table 1 outlines the proportions of individuals that experienced each birth stressor within our sample. These proportions are well within the range normally seen for the general population.

Insert Table 1 about here.

Since we were dealing with sensory deficits which were not so severe so as to incapacitate an individual, we judged good versus poor sensory ability in a relative rather than an absolute manner. The simplest way to do this was to rank order individuals in the sample on the basis of sensory capacities, judging those who fell in the lower half as having relatively poor (or certainly poorer) capacity. For the purposes of analysis, we then employed a median split. Subjects above the median were classified as normal, and those below as deficient for the sensory capacity being considered.

Chi-square tests of association were conducted between each birth stressor and each sensory capacity to determine whether the proportion of individuals with poorer

**Table 1: Proportion of Individuals
Experiencing Birth Stressors**
(N = 1187)

	% Normal	Sample % Stressed	Population % Stressed
Long Labour	84.3	15.7	-
Breech	96.7	3.3	3-4
Hypoxia	96.1	3.9	-
Forceps	94.1	5.9	5.0
C-Section	92.4	7.6	14.0 (1970)
Twins	98.4	1.6	1.2
Premature	90.0	10.0	10.1
Low Weight	87.7	12.3	6.9
Birth Order	42.6	57.4	-

(from Gabbe, Niebyl & Simpson)

sensory capacities was greater among the birth stressed individuals or non-birth stressed individuals. In addition, stepwise regression analyses were performed to determine the relative contributions of the birth stressors to the overall predictability of the sensory deficits. Although most significance levels reported are two-tailed, since directional hypotheses were stated before the data were analysed, any results found to be significant by one-tailed tests have also been included. We have specifically noted those instances where significance in only one-tailed.

Snellen Acuity

Differences in the proportion of individuals with poor visual acuity with birth stress or without birth stress were tested using chi-square tests of association. Each birth stressor was examined independently. Since some subjects did not know whether a particular birth risk factor was present, the sample size varies across birth risk categories. The minimum number of subjects in any of the following comparisons was 1129.

Insert Figure 1 about here.

As can be seen in Figure 1, significantly more individuals with poor acuity were found to have suffered from prolonged labour than not, $\chi^2 (1) = 4.563, p < .05$. In addition, more individuals with poor acuity were likely to have been born by Caesarian section than born vaginally, $\chi^2 (1) = 4.909, p < .05$. A greater number of subjects with poor acuity were also found to have been one of twins or triplets, $\chi^2 (1) = 4.093, p < .05$. Moreover, significantly more individuals with poor acuity were either firstborns or the

Figure 1: Relative Visual Acuity by Birth Stress Factors
(Minimum N = 1129)

(Starred comparisons are statistically significant - see text for details.)

fifth or sixth child, as opposed to being the second, third or fourth child in the family, $\chi^2(1) = 3.861$, $p < .05$. Individuals born by breech presentation seemed to be at greater risk for having poor acuity, although this trend was not statistically significant, $\chi^2(1) = 2.45$, $p = .12$. The presence or absence of hypoxia, instrument birth, premature birth or low birth weight did not appear to affect the proportion of individuals with poor acuity.

In addition to the chi-square tests, relative risk measures were calculated which describe the likelihood of having poor acuity when a given birth stressor has actually been present, compared to the likelihood when the birth stressor is absent. If the likelihood of having an acuity deficit is greater for the incidence rather than absence of a certain birth stressor, the relative risk will be greater than one, whereas if the likelihood is smaller given the incidence of a birth stressor, the relative risk will be less than one. These calculations may be seen in Table 2.

Insert Table 2 about here.

The relative risk measures indicate that twins or triplets are one and a half times more likely than singletons to have acuity deficits, while those born by Caesarian section are one and a quarter times more likely to develop acuity deficits. Additionally, individuals experiencing long labour are 17% more likely to have poor visual acuity, while firstborns and those born after the fourth child are 12% more likely to have acuity deficits.

The relative contributions of the birth stress factors on the predictability of acuity deficits were examined by running stepwise regression analyses. For Snellen acuity, the

Table 2: Relative Risk Measures for Visual Acuity

<u>Birth Stressors</u>	<u>Relative Risk</u>	<u>95% Confidence Intervals</u>
Long Labour	1.17*	1.02 - 1.34
Breech Birth	1.25	.98 - 1.60
Hypoxia	.94	.70 - 1.27
Forceps	.89	.68 - 1.15
Caesarian Section	1.24*	1.05 - 1.48
Multiple Birth	1.47*	1.11 - 1.93
Prematurity	.93	.76 - 1.13
Low Birth Weight	1.12	.96 - 1.30
Birth Order	1.12*	1.00 - 1.26

(Starred relative risk indexes are statistically significant - see text for details.)

first variable entered into the equation was prolonged labour, thus supporting the chi-square findings, and reiterating the strength of prolonged labour in predicting acuity deficits. Birth by Caesarian section was also found to predict the residual variance associated with poor acuity, as Caesarian section was the second variable to be entered into the equation. No other variables were entered into the equation. The final multiple regression was $R = .0718$, $p = .055$.

Macular Suppression

For macular suppression, the minimum number of subjects in any statistical comparison was 1217. As can be seen in Figure 2, five birth stressors were associated with a greater incidence of macular suppression.

Insert Figure 2 about here.

As with acuity, a greater incidence of macular suppression was found amongst individuals suffering from a prolonged labour than those delivered within the normal time period, $\chi^2(1) = 8.74$, $p < .01$. Similarly, individuals who suppressed more were more likely to have been delivered by Caesarian section than delivered vaginally, $\chi^2(1) = 2.45$, $p < .05$. Individuals presenting in breech fashion, born of low weight and those being the first, fifth or sixth child in the family also suppressed more than their non-birth stressed counterparts [$\chi^2(1) = 2.83$, $p < .05$ (one-tailed), $\chi^2(1) = 2.75$, $p < .05$ (one-tailed), $\chi^2(1) = 3.42$, $p < .05$ (one-tailed), respectively]. The presence or absence of hypoxia, instrument birth, multiple birth or premature birth did not appear to affect the proportion of

Figure 2: Relative Macular Suppression by Birth Stress Factors
(Minimum N = 1217)

(Starred comparisons are statistically significant - see text for details.)

individuals with greater macular suppression.

Indices of relative risk, as seen in Table 3, demonstrate that individuals experiencing prolonged labour were 25% more likely to have stronger macular suppression than their non-birth stressed cohorts. Similarly, individuals born by Caesarian section were 26% more likely to be classified as deficient in terms of macular suppression. Breech births were 28% more likely to suppress more than average, while individuals of low birth weight and of high risk birth order were 15% and 12% more likely, respectively, to have strong macular suppression.

Insert Table 3 about here.

Regression analyses indicated that many of the birth stressors contributed to the predictability of macular suppression. The first variable entered into the equation was the birth order of the child (where being the first or beyond the fourth child puts oneself at risk). The other contributing variables, in order of entrance into the equation, were prolonged labour, Caesarian section, prematurity, low birth weight and hypoxia. The final multiple regression coefficient was $R = 0.1281$, $p < .01$.

Stereopsis

As can be seen in Figure 3, six birth stressors were found to be significantly associated with a decreased level of stereopsis (minimum $N = 901$).

Table 3: Relative Risk Measures for Macular Suppression

<u>Birth Stressors</u>	<u>Relative Risk</u>	<u>95% Confidence Intervals</u>
Long Labour	1.25*	1.09 - 1.44
Breech Birth	1.28*	.99 - 1.66
Hypoxia	1.13	.86 - 1.50
Forceps	1.07	.84 - 1.36
Caesarian Section	1.26*	1.05 - 1.51
Multiple Birth	1.34	.95 - 1.90
Prematurity	.91	.73 - 1.12
Low Birth Weight	1.15*	.98 - 1.36
Birth Order	1.12*	.99 - 1.27

(Starred relative risk indexes are statistically significant - see text for details.)

Insert Figure 3 about here.

A significantly greater proportion of individuals with a stereo deficit were found to have endured a prolonged labour during birth, $\chi^2(1) = 12.16$, $p < .001$. In addition, a greater proportion of the individuals with poor stereopsis were also found to be twins or triplets rather than singletons, $\chi^2(1) = 8.50$, $p < .01$. Similarly, a greater number of subjects with poor stereopsis were the first, fifth or sixth child born to a family, $\chi^2(1) = 4.13$, $p < .05$. Individuals born by breech presentation, Caesarian section or low birth weight were also found to be more numerous among the stereo deficient than were non-birth stressed individuals [$\chi^2(1) = 3.70$, $p < .05$, (one-tailed), $\chi^2(1, N = 954) = 2.88$, $p < .05$ (one-tailed), $\chi^2(1, N = 968) = 3.41$, $p < .05$ (one-tailed), respectively]. No differences between the proportions of birth stressed and non-birth stressed stereo-deficient individuals were found for infants experiencing hypoxia, instrument births or those born prematurely.

Relative risk calculations, as seen in Table 4, demonstrate that long labour infants were one and a third times more likely to have deficient stereopsis than their non-stressed peers.

Insert Table 4 about here.

Additionally, twins and triplets were 86% more likely to develop poor stereopsis than singletons. Individuals of high-risk birth order (1st, 5th or 6th child) were 15% more

Figure 3: Relative Stereopsis by Birth Stress Factors
(Minimum N = 901)

(Starred comparisons are statistically significant - see text for details.)

Table 4: Relative Risk Measures for Stereopsis

<u>Birth Stressors</u>	<u>Relative Risk</u>	<u>95% Confidence Intervals</u>
Long Labour	1.31*	1.15 - 1.52
Breech Birth	1.37*	1.05 - 1.77
Hypoxia	1.05	.78 - 1.43
Forceps	1.00	.78 - 1.30
Caesarian Section	1.20*	.98 - 1.46
Multiple Birth	1.86*	1.55 - 2.23
Prematurity	.88	.70 - 1.12
Low Birth Weight	1.18*	1.00 - 1.40
Birth Order	1.15*	1.01 - 1.30

(Starred relative risk indexes are statistically significant - see text for details.)

likely than others to develop stereo problems. Breech presentation infants, infants delivered by Caesarian section and those born of low birth weight were 37%, 20% and 18% more likely, respectively, to show stereopsis deficits than were individuals who did not experience such birth stressors.

Once again, numerous variables were found to contribute significantly to the prediction of stereo deficits, the strongest of these predictors, as with acuity, was long labour. Additionally, multiple birth, instrument birth and birth order, in sequence, were found to significantly account for residual variance in the equation (Multiple $R = 0.1399$, $p < .001$).

Colour Discrimination

The histogram of Figure 4 demonstrates that a greater number of colour deficient individuals experienced prolonged labours than labours of regular length, $\chi^2(1) = 3.66$, $p < .05$ (one-tailed). No other differences in proportions were observed for colour deficient individuals on any of the other birth stressors. As the number of subjects in the colour discrimination sample was nearly half that obtained for the other visual capacities (with the minimum N for each comparison being 498), it is, however, possible that more differences would have been drawn out had a larger sample size been obtained.

Insert Figure 4 about here.

Individuals who experienced a prolonged labour were found to be 22% more likely than non-birth stressed individuals to show colour discrimination deficiencies. This

Figure 4: Relative Colour Discrimination by Birth Stress Factors
(Minimum N = 498)

(Starred comparisons are statistically significant - see text for details.)

relative risk calculation, as well as those for the remaining birth stressors, may be seen in Table 5.

Insert Table 5 about here.

The regression analysis revealed that breathing difficulty, although not significant in the chi-square test, contributed significantly to the prediction of poor colour discrimination. Long labour was also found to account for a significant portion of the residual variance (Multiple R = .1272, $p < .05$).

Puretone Hearing Threshold

Significantly more individuals with poor puretone hearing were found to be twins or triplets, as opposed to singletons, $\chi^2 (1) = 4.093$, $p < .05$, as can be seen in Figure 5. No other birth stressor was found to be associated with the prevalence of puretone hearing deficiencies (minimum N = 928).

Insert Figure 5 about here.

As can be seen in Table 6, twins and triplets were 66% more likely to have hearing threshold problems than their singly-born peers. None of the remaining birth stressors approached significance for the relative risk computations.

Table 5: Relative Risk Measures for Colour Discrimination

<u>Birth Stressors</u>	<u>Relative Risk</u>	<u>95% Confidence Intervals</u>
Long Labour	1.22*	1.01 - 1.47
Breech Birth	1.12	.75 - 1.69
Hypoxia	1.18	.84 - 1.67
Forceps	.97	.70 - 1.34
Caesarian Section	1.11	.86 - 1.42
Multiple Birth	1.26	.71 - 2.24
Prematurity	.94	.71 - 1.24
Low Birth Weight	1.05	.84 - 1.33
Birth Order	1.09	.93 - 1.29

(Starred relative risk indexes are statistically significant - see text for details.)

Figure 5: Relative Pure Tone Threshold by Birth Stress Factors
(Minimum N = 928)

Birth Stressors

(Starred comparisons are statistically significant - see text for details.)

Insert Table 6 about here.

In accordance with the above results, a regression equation found multiple birth to be the most predictive variable of hearing threshold problems. In addition, long labour, instrument birth and breathing difficulty were found to account for a significant amount of the successive residual variances (Multiple $R = .1471$).

Speech Recognition

None of the chi-square tests of association reached statistical significance for any of the birth stressors, as can be seen in Figure 6 (minimum $N = 931$).

Insert Figure 6 about here.

It can therefore be understood that no measurable differences on this task are produced by the presence or absence of the tested birth stressors. In a similar vein, no variables were found to be significantly predictive of speech recognition problems, as indicated by the lack of a significant equation in the regression analysis (the Multiple R , with long labour and multiple birth entered in was $.0602$, $p = .185$). Relative risk calculations are presented in Table 7.

Insert Table 7 about here.

Table 6: Relative Risk Measures for Pure Tone Hearing

<u>Birth Stressors</u>	<u>Relative Risk</u>	<u>95% Confidence Intervals</u>
Long Labour	.96	.82 - 1.14
Breech Birth	1.17	.88 - 1.55
Hypoxia	.86	.62 - 1.21
Forceps	1.15	.93 - 1.42
Caesarian Section	1.12	.92 - 1.36
Multiple Birth	1.66*	1.30 - 2.10
Prematurity	.86	.69 - 1.08
Low Birth Weight	.95	.79 - 1.15
Birth Order	.98	.86 - 1.11

(Starred relative risk indexes are statistically significant - see text for details.)

Figure 6: Relative Speech Recognition by Birth Stress Factors
(Minimum N = 931)

Birth Stressors

(Starred comparisons are statistically significant - see text for details.)

Table 7: Relative Risk Measures for Speech Recognition

<u>Birth Stressors</u>	<u>Relative Risk</u>	<u>95% Confidence Intervals</u>
Long Labour	.97	.82 - 1.15
Breech Birth	1.14	.84 - 1.54
Hypoxia	.88	.63 - 1.24
Forceps	.97	.75 - 1.25
Caesarian Section	1.11	.91 - 1.35
Multiple Birth	1.05	.64 - 1.75
Prematurity	.99	.81 - 1.22
Low Birth Weight	1.06	.89 - 1.27
Birth Order	.96	.84 - 1.09

(Starred relative risk indexes are statistically significant - see text for details.)

Sound Localization

A greater number of individuals who performed poorly at the sound localization task were found to have experienced prolonged labours than not, $\chi^2(1) = 2.93$, $p < .05$ (one-tailed), as can be seen in Figure 7 (minimum $N = 926$).

Insert Figure 7 about here.

This difference translates into a 15% greater likelihood of having poor sound localizing skills, given a prolonged labour. The remaining relative risk factors may be found in Table 8.

Insert Table 8 about here.

As with speech recognition, no variables were found to be significantly predictive of sound localization problems, as indicated by the lack of a significant equation in the regression analysis (Multiple R, with multiple birth entered in equals .0445, $p = .176$).

Additional Analyses

In addition to the above mentioned chi-square tests of association, relative risk computations and regression analyses, chi-square tests were performed to determine whether any sex differences existed for any of the sensory capacities. No such differences in the proportions of males or females were found for any of the capacities, although there was a trend for males to be over-represented in the poor colour

Figure 7: Relative Sound Localization Ability by Birth Stress Factors

(Minimum N = 926)

(Starred comparisons are statistically significant - see text for details.)

Table 8: Relative Risk Measures for Sound Localization

<u>Birth Stressors</u>	<u>Relative Risk</u>	<u>95% Confidence Intervals</u>
Long Labour	1.15*	.99 - 1.34
Breech Birth	.92	.63 - 1.34
Hypoxia	1.11	.84 - 1.47
Forceps	.85	.64 - 1.14
Caesarian Section	1.11	.90 - 1.37
Multiple Birth	1.26	.81 - 1.94
Prematurity	1.03	.84 - 1.27
Low Birth Weight	1.06	.88 - 1.27
Birth Order	.94	.82 - 1.07

(Starred relative risk indexes are statistically significant - see text for details.)

discrimination category. The absence of sex differences justifies the pooling of male and female subjects in the preceding analyses.

A possibility exists that individuals with poor sensory capacities may be looking for a reason for their deficits and hence may seek out information about their births and uncover more potential risk factors. This would produce spurious opponent relationships between birth stressors and poorer sensory ability. To test for this, t-tests were conducted to ascertain whether individuals classified as sensory poor were more knowledgeable about their births than those classified as sensory normal. Results indicated that both groups left approximately the same number of blanks on the birth stress questionnaire. This suggests that the rate of false negatives was also similar across the sensory poor and sensory normal groups. One can therefore conclude that the two groups did not differ in terms of their knowledge of the events surrounding their births, and presumably also rule out the possible confound outlined above.

Chapter Four: Discussion

Summary of Results

As predicted, numerous birth stress factors were found to be significantly associated with deficits in the sensory capacities that were investigated in this study. In order to get a bird's eye view of the results, a summary table of the chi-square results was created that indicates which birth risk factors, if any, reached statistical significance for each of the sensory capacities.

Insert Table 9 about here.

By summing the number of significant findings across the rows of Table 9, we were able to derive a measure of the relative susceptibility of each sensory capacity to birth stressors. As can be seen in Table 9, stereopsis was found to be the capacity the most affected by birth stressors, with six of the nine birth risk factors being associated with stereo deficits. Snellen visual acuity and macular suppression were also strongly affected by the presence of birth stressors; five of the risk factors were associated with greater suppression, and four of the risk factors associated with poorer acuity. The other visual capacity, colour discrimination, was affected only by long labour.

As predicted, the auditory capacities seemed to be only mildly affected by birth stress. Pure-tone hearing thresholds were significantly lower only for those individuals who were twins or triplets. Sound localization ability was found to differ amongst groups only if subjects experienced long labour. Finally, no differences were found in speech

Table 9. Summary Table of Significant Findings for Sensory Capacity by Birth Stress Factors

<u>Sensory Capacity</u>	<u>Birth Risk Factors</u>									Total
	<u>Long Labour</u>	<u>Breech</u>	<u>Hypoxia</u>	<u>Forceps</u>	<u>Caesarian</u>	<u>Twins</u>	<u>Prematurity</u>	<u>Low Birth Weight</u>	<u>Birth Order</u>	
Acuity	*				*	*			*	4
Macular Suppression	*	*			*			*	*	5
Stereopsis	*	*			*	*		*	*	6
Colour	*									1
Puretone Hearing						*				1
Speech										0
Sound Localization	*									1
Total	5	2	0	0	3	3	0	2	3	18

(Stars indicate significant differences - please see text for details.)

recognition ability regardless of whether subjects were stressed or not. The implication of the relative susceptibilities of the various sensory capacities within and across the modalities will be discussed shortly.

A snap-shot of the relative impact of each of the birth stressors on sensory capacities as a whole was derived by summing the number of significant findings down the columns in Table 9. The incidence of long labour was found to have had the most impact, as it was associated with five of the seven measured capacities. The incidence of multiple birth was found to be the next strongest birth risk, impacting on two visual capacities and one auditory capacity. Both Caesarian section and high risk birth order were associated with three visual deficits but no auditory deficits. Breech presentation and low birth weight were moderately associated with two of the visual capacities, but no auditory deficits. Surprisingly, neither hypoxia, instrument birth or prematurity was associated with deficits in any of the capacities examined. The question of why some of the birth stressors should impact more than others on sensory capacities will be addressed shortly.

Relative susceptibilities of sensory capacities

As predicted, the visual capacities were found to be more vulnerable than the auditory capacities to the negative effects of birth stress. As I noted in the introduction, one way of understanding this is in terms of the relative development of the senses at birth. While the auditory system is functioning quite well at birth, the visual system is still developing, and is not adult-like until about 6 months postnatal. As such, any disruptive forces during pregnancy or labour have the potential to alter the normal

development of visual pathways or to disrupt the pattern of cell proliferation and dendritic growth in the sensory cortex or the receptor itself.

This notion of a negative relationship between the maturity of a sensory system at birth and the amount of insult that the system can suffer remains plausible when examining the relative susceptibilities to birth stress within the visual modality as well, as the data of this study tend to suggest that the earlier a capacity is expected to function, the less likely will it be altered by any negative events associated with the intrapartum period. This study found that stereopsis was affected by more birth stressors than was snellen acuity, which in turn was affected by more birth stressors than was colour discrimination. In examining the time periods when these capacities appear to come "on-line", a developmental sequence is evidenced which follows the same order as the relative susceptibilities.

Colour vision, for example, is thought to be functioning fairly reasonably at birth (Teller & Bornstein, 1987), with the possible exception that the short wavelength system may not function until the 2nd month postnatal, and as such should be little affected by birth-related incidents. In accordance with this hypothesis, this study demonstrated that colour discrimination was little affected by birth stressors, although there was some suggestion that discrimination confusion did arise around the blue colours. Snellen acuity in infants is thought to improve rapidly between birth and 6 months of age, with the rate of improvement the greatest between the first and second months (Atkinson et al., 1979). As such, visual acuity would be expected to be relatively more prone to developmental problems than colour discrimination, as was demonstrated in the present

study. Finally, depth perception is thought to come on-line even later in infancy, with the first indication of binocular function at three to four months of age (Atkinson, 1984). Once again, the later development could cause the capacity to be even more prone than acuity and colour discrimination to developmental alterations caused by birth stress, a hypothesis that was once again confirmed in this study.

Relative impact of birth risk factors

In addition to determining which sensory capacities were more affected by birth stress, this study also examined the relative impact of the birth stressors. Prolonged labour overwhelmingly proved to be the strongest of the birth stressors, while hypoxia, prematurity and instrument birth proved to have mild if any impact when examined alone. One possible explanation for why long labour should so strongly affect the sensory capacities is that many different perinatal problems may co-occur with a long second stage. While hypoxia by itself was not associated with any sensory deficits, breathing difficulty is a common result of long labour, as the umbilical cord may be squeezed, preventing adequate oxygen from getting to the infant. Similarly, while instrument use examined alone was not associated with sensory deficits, low forceps are not uncommonly used during long labours to facilitate the birth of the child. Thus, it may be that hypoxia and instrument birth, while not sufficient enough to cause sensory deficits on their own, may be assisting agents working in conjunction with what is understood to be long labour.

That prematurity did not contribute to the sensory deficits as was predicted may be due to the nature of the birth stress it produces. With the current technology,

premature infants, unless they are extremely under-developed, are easily maintained in an environment conducive to appropriate development without further disruption. It may be that prematurity on its own is not a powerful enough stressor to cause sensory deficits, and only when the infant is subjected to further insults during the birth process are sensory deficits probable.

The second strongest birth stressor was found to be multiple pregnancy in this study, not surprising when one considers the quality of the uterine environment and the intrapartum events associated with twinning. All through fetal development, the two fetuses must share a limited amount of space, nutrients and oxygen, and therefore it is not surprising that twins are often born of low birth weight, either being small for gestational age or premature. As in the case of long labour, it may be that multiple births assure, in addition to the actual twinning, enough moderate risk factors to alter the normal development of sensory capacities.

Both the Caesarian Section risk factor and the birth order risk factor, where firstborns and those born after the fourth child are at risk, are but markers for the likelihood of a difficult birth. While these factors alone are not known to be hazardous to the infant's health, they co-occur frequently with any number of other birth risk factors, and as such are found implicated in sensory deficits.

In general, it should be stated that the lack of finding sensory deficits in the presence of individual birth stressors does not necessarily imply that the risk factors have absolutely no detrimental effect on the sensory systems. Rather, it implies that the presence of an individual birth risk factor, as determined by the questionnaire, is not

sufficient enough, under the circumstances, to produce reliable sensory deficits. The questionnaire used to establish the amount of birth stress associated with the participant's birth was of a dichotomous nature, and thus less statistically powerful than had a questionnaire of a continuous nature been used (i.e. How premature were you? How long was your mother in labour? For how long did you have trouble breathing?). Obviously, most individuals would have trouble completing a more extensive questionnaire, as would their mothers. It could well be that stronger results might have been found had hospital records been available.

Implications of the study

The implications of the study may be examined from two different angles; from a theoretical view-point, examining the possible inclusion of sensory deficits in the Alinormal Syndrome (Coren & Searleman, 1987) and from a practical view-point, examining the possible effects of intervention. Both will be discussed in turn.

The Alinormal Syndrome. It has been well established that major neurological damage during birth can result in major physical and cognitive pathologies. Coren & Searleman (1987) and Coren & Halpern (1991) have suggested that mild birth stress or mildly atypical intrauterine environments may also result in pathological sequelae which are much more subtle. Such covert trauma tends not to render birth stressed individuals manifestly abnormal, but rather alinormal (where the suffix 'ali' conveys the meaning of elsewhere or otherwise), hence for such individuals gross inspection may not reveal any major deviations from the norm.

Coren & Searleman (1987) suggested that the consequences of a difficult birth

may create a fairly predictable syndrome of behavioural markers. These include left-handedness (deviation from the dextral norm), inverted writing posture (Searleman, Porac & Coren, 1982), difficulty falling asleep and frequent night awakenings (Coren & Searleman, 1985) and a delay in physical maturation (Achenbach, 1974). The present study, showing a relationship between birth stressors and sensory abilities, suggests that sensory capacities could be viewed as yet another facet of the alinormal syndrome, and further demonstrates the far-reaching effects of an abnormal birth. Before such a suggestion should be adopted, additional research should be conducted to determine whether sensory deficits do indeed covary with left-handedness, sleep disorders and rate of physical maturation.

Intervention. If the effects of birth stress are indeed as far-reaching as they appear to be, any technological advancement encouraging more normal births to occur would be of benefit. A reduction in the number of difficult births could correspond to a decrease in the morbidity rate of mild sensory and cognitive deficits. Obviously, such a task is out of the hands of psychologists, and methods of intervention should focus more on providing enriching environments during the first few months of life that would encourage the normal development of the sensory capacities.

The growing infant learns about the world through the senses, and thus any disruptions in their normal sensory development may lead to delays in understanding how to interact with people and objects in the environment. Eyesight and hearing are often not tested until children are well into school, and therefore sensory deficits may be at the root of some of the perceptual and cognitive developmental delays associated with

birth stress, including sensory-motor, learning, and social skills. In addition, poor visual acuity has been found to be associated with decreased extraversion, while poor hearing has been found to be associated with increased neuroticism and decreased openness to experience (Coren & Harland, 1994). As such, birth stressed individuals with sensory deficits may not possess the basic interactive social skills or the drive necessary to take full advantage of the social and educational aspects of school. For this reason it might be advisable to have mothers report any birth stressors associated with a child when initially enrolling him in school. The existence of a history of birth risk factors could then be used as a flag to identify children as candidates for formal sensory testing early in their primary education. This could help mitigate any long term educational or personality problems.

Every parent's dream is to hear that his newborn baby has ten fingers and ten toes. While it is generally concluded from such a remark that the infant is developmentally and neurologically normal, the Alinormal Syndrome stresses that this may be far from the truth. Until the incidence of mild sensory and cognitive deviations rivals the low mortality rate we now appreciate, psychologists, pediatricians and obstetricians must work together not only through pregnancy and labour to prevent abnormalities from arising but also through childhood to develop effective intervention techniques that facilitate the normal growth and development of perinatally compromised infants.

References

- Achenbach, T. M. (1984). Developmental Psychopathology. New York: Ronald Press.
- Alexopoulos, K. A. (1973). The importance of breech delivery in pathogenesis of brain damage. Clinical Pediatrics (Philadelphia), 12, 248-249.
- Atkinson, J. (1984). Human visual development over the first 6 months of life: A review and a hypothesis. Human Neurobiology, 3, 61-74.
- Atkinson, J., Braddick, O., & French, J. (1979). Contrast sensitivity of the human neonate measured by the visual evoked potential. Investigative Ophthalmology and Vision Research, 18, 210-213.
- Avery, G. (1985). Effects of social, cultural and economic factors on brain development. In J. M. Freeman (Ed.), Prenatal and perinatal factors associated with brain disorders (NIH Pub. #85-1149). Bethesda, MD: National Institutes of Health.
- Bakketeig, L. S., & Hoffman, H. J. (1979). Perinatal mortality by birth order within cohorts based on sibship size. British Medical Journal, 2, 693-696.
- Berkowitz, G. S. (1981). An epidemiologic study of preterm delivery, American Journal of Epidemiology, 113, 81-92.
- Bradley, R. M. & Mistretta, C. M. (1975). Fetal sensory receptors. Physiological Reviews, 55, 352-382.
- Broman, S. H. (June, 1978). Outcome of adolescent pregnancy: A report from the Collaborative Perinatal Project. Paper presented at the Workshop on Developmental Followup on Infants Born at Risk, 13th Annual Conference of the Association for the Care of Children in Hospitals, Washington, D. C.

- Butler, N. R. & Goldstein, H. (1973). Smoking in pregnancy and subsequent child development. British Medical Journal, 4, 573-575.
- Butler, N. R., Goldstein, H. & Ross, E. M. (1972). Cigarette smoking in pregnancy: Its influence on birthweight and perinatal mortality. British Medical Journal, 2, 127-130.
- Campbell, L. A. (1985). The very low birth weight infant: sensory experience and development. Topics in Clinical Nursing, 6, 19-33.
- Capuron, J. C. (1820). *Traite des Maladies des Enfants*. Ite Edition, Paris, p. 7.
- Caputo, D. V., Goldstein, K. M & Taub, H. B. (1981). Neonatal compromise and later psychological development: A 10-year longitudinal study. In S. L. Friedman & M. Sigman (Eds.), Preterm birth and psychological development (pp 180-212). New York: Academic Press.
- Caputo, D. V. & Mandell, W. (1970). Consequences of low birth weight. Developmental Psychology, 3, 363-383.
- Churchill, J. A., & Colfelt, R. (1963). Etiologic factors in athetotic cerebral palsy. Archives of Neurology, 9, 400-406.
- Cochrane, C., and Robertson, A. (1973). The Life Events Inventory: A measure of the relative severity of psycho-social stressors. Journal of Psychosomatic Research, 17, 135.
- Cohen, W. R., Newman, L. & Friedman, E. A. (1980). Risk of labour abnormalities with advancing maternal age. Obstetrics and Gynecology, 55, 414-416.
- Commeey, J. O. & Fitzhardinge, P. M. (1979). Handicap in the preterm small-for-

- gestational age infant, Journal of Pediatrics, 94, 779-786.
- Coren, S. (1992). The Left-hander Syndrome. New York: The Free Press.
- Coren, S. & Hakstian, A. R. (1988). Colour vision screening without the use of technical equipment: Scale development and cross-validation. Perception and Psychophysics, 43, 115-120.
- Coren, S. & Hakstian, A. R. (1989). Validation of a self-report inventory for the measurement of visual acuity. International Journal of Epidemiology, 18, 451-456.
- Coren, S. & Hakstian, A. R. (1992). The development and cross-validation of a self-report inventory to assess pure-tone threshold hearing sensitivity. Journal of Speech and Hearing Research, 35, 921-928.
- Coren, S. & Halpern, D. F. (1991). Left-handedness: a marker for decreased survival fitness. Psychological Bulletin, 109, 90-106.
- Coren, S. & Harland, R. E. (1994). Personality correlates of variations in visual and auditory abilities. Personality and Individual Differences (in press).
- Coren, S. & Searleman, A. (1985). Birth stress and self-reported sleep difficulty. Sleep, 8, 222-226.
- Dann, M., Levine, S. Z. & New, E. V. (1964). A long-term follow-up study of small premature infants. Pediatrics, 33, 945-955.
- De Crispigny, L. J. C. & Pepperrell, R. J. (1979). Perinatal mortality and morbidity in breech presentation. Obstetrics and Gynecology, 53, 141-145.
- Dowding, V. M. (1981). New assessment of the effects of birth order and socioeconomic status on birth weight, British Medical Journal, 282, 683-686.

- Drillien, C. M. (1961). The incidence of mental and physical handicaps in school-age children of very low birth weight. Pediatrics, 27, 452-464.
- Dwyer, J. F. (1974). Teenage Pregnancy. American Journal of Obstetrics and Gynecology, 118, 373-376.
- Eastman, N. J., Kohl, S. G., Maisel, J. E. & Kavalier, F. (1962). The obstetrical background of 753 cases of cerebral palsy. Obstetrical and Gynecological Survey, 17, 459.
- Eisenberg, R. B., Coursin, D. B. & Rupp, N. R. (1966). Habituation to an acoustic pattern as an index of differences among human neonates. The Journal of Auditory Research, 6, 239-248.
- Fantz, R. L. & Fagan, J. F. (1975). Visual attention to size and number of pattern details by term and preterm infants during the first six months. Child Development, 46, 3-18.
- Field, T. M., Dempsey, J. R., Hatch, J., Ting, G. & Clifton, R. K. (1979). Cardiac and behavioral responses to repeated tactile and auditory stimulation by preterm and term neonates. Developmental Psychology, 15, 406-416.
- Fitzhardinge, P. M. & Pape, K. E. (1981). Follow-up studies of the high risk newborn. In G. Avery (Ed.), Neonatology: Pathophysiology and management of the newborn (2nd ed.) p 350. Philadelphia: Lippincott.
- Fitzhardinge, P. M. & Steven, E. M. (1972). The small for dates infant: Later growth patterns. Pediatrics, 49, 671-681.
- Flamm, B. L. (1990). Birth after Cesarean. New York: Prentice Hall Press.

- Freeman, J. (1985). Summary. In J. M. Freeman (Ed.), Prenatal and perinatal factors associated with brain disorders (NIH Pub #85-1149) (pp. 437-450). Bethesda, MD: National Institutes of Health.
- Friedman, E. A. (1987). Midforceps delivery: no? Clinical Obstetrics and Gynecology, 30, 93-105.
- Friedman, S. L., Jacobs, B. S. & Werthman, M. W. (1981). Sensory Processing in pre- and full-term infants in the neonatal period. In S. L. Friedman & M. Sigman (Eds.), Preterm birth and psychological development (pp 159-178). New York: Academic Press.
- Freud, S. (1897). Infantile cerbrallahmung. In Nothnagel's Specielle Pathologie und Therapie, 12. Vienna.
- Gabbe, S. G., Niebyl, J. R. & Simpson, J. L. (1991). Obstetrics: Normal & Problem Pregnancies (2nd Edition) p. 223. New York: Churchill Livingstone.
- Gottlieb, G. (1971). Ontogenesis of Sensory Function in Birds and Mammals. In E. Taubach and R. Shaw (Eds.), The Biopsychology of Development. New York: Academic Press.
- Gray, J. W. & Dean, R. S. (1991). Neuropsychology of Perinatal Complications, New York: Springer.
- Hanson, J. W., Jones, K. L. & Smith, D. W. (1976). Fetal alcohol syndrome: Experience with 41 patients. Journal of the American Medical Association, 235, 1458-1460.
- Hanson, J. W. (1977). Unpublished manuscript.
- Harvey, D., Cooke, R. W. I. & Levitt, G. A. (1989). The Baby under 1000 g p.5.

Boston: Wright.

Hayashi, R. H. (1987). Midforceps delivery: yes? Clinical Obstetrics and Gynecology, 30, 91-92.

Herrgard, E., Luoma, L., Tuppurainen, K., Karjalainen, S. & Martikainen, A. (1993).

Neurodevelopmental profile at five years of children born at $\leq$ weeks gestation.

Developmental Medicine and Child Neurology, 35, 1083-1096.

Hobel, C. J. (1985). Factors before pregnancy that influence brain development. In J.

M. Freeman (Ed.), Prenatal and perinatal factors associated with brain disorders

(NIH Pub #85-1149) (pp. 197-237). Bethesda, MD: National Institutes of Health.

Hodgson, W. R. (1980). Basic Audiologic Evaluation. Baltimore: Williams & Wilkins.

Hunt, J. V., Tooley, W. H. & Harvin, D. (1982). Seminars in Perinatology, 6(4), 280-287.

Iosub, S., Fuchs, M., & Bingol, N. (1981). Fetal alcohol syndrome revisited. Pediatrics,

68, 475-479.

Jones, K. L. & Smith, D. W. (1975). The fetal alcohol syndrome. Teratology, 12, 1-10.

Jurado, L. & Miller, G. L. (1968). Breech presentation. American Journal of Obstetrics and Gynecology, 101, 183-189.

Kajanoja, P. & Widholm, O. (1978). Pregnancy and delivery in women aged 40 and over. Obstetrics and Gynecology, 51, 47-51.

Katona, F. & Berenyi, M. (1974). Differential reactions and habituation to acoustical and visual stimuli in neonates. Activitas Nervosa Superior, 16, 305.

Kaupila, O. (1975). The perinatal mortality in breech deliveries and observations on

- affecting factors. Acta Obstetricia Gynecologica Scandinavica, 39, 29-79.
- Lee, C. Y. (1987). Shoulder dystocia. Clinical Obstetrics and Gynecology, 30, 77-82.
- Lee, H. & Barratt, M. S. (1993). Cognitive development of preterm low birth weight children at 5 to 8 years old. Developmental and Behavioral Pediatrics, 14, 242-249.
- Little, W. J. (1862). On the influence of abnormal parturition, difficult labors, premature birth, and asphyxia neonatorum on the mental and physical condition of the child, especially in relation to deformities. Transcripts of the Obstetrics Society of London, 2, 293.
- Low, J. A., Galbraith, R. S., Muir, D. W., Killen, H. L., Pater, E. A., & Karchmar, E. J. (1984). Factors associated with motor and cognitive deficits in children after intrapartum fetal hypoxia. American Journal of obstetrics and Gynecology, 148, 533-539.
- Lubchenco, L. O., Horner, F. A., Reed, L. H., Hix, I. E., Metcalf, D., Cohig, R., Elliott, H. C. & Bourg, M. (1963). Sequelae of Premature Birth. American Journal of Diseases of Children, 106, 135-149.
- Miller, H. D., Hassanein, K. & Hensleigh, P. A. (1978). Maternal factors in the incidence of low birth weight infants among black and white mothers. Pediatric Resident, 12, 1016.
- Muller, P. F., Campbell, H. E., Graham, W. E., Brittain, H., Fitzgerald, J. A., Hogan, M. A., Muller, B. H. & Rittenhouse, A. H. (1971). Perinatal factors and their relationship to mental retardation and other parameters of development.

American Journal of Obstetrics and Gynecology, 109, 1205.

- Newton, T. W., Webster, P. A. & Binu, P. S. (1979). Psychosocial stress in pregnancy and its relation to the onset of premature labour. British Medical Journal, 2, 411-413.
- Nielsen, T. F. & Hokegard, K. H. (1984). Cesarean section and intraoperative surgical complications. Acta Obstetricia Gynecologica Scandinavica, 63, 103.
- Niswander, K. R. & Gordon, M. (1972). The Women and Their Pregnancies. Philadelphia: WB Saunders.
- Niswander, K. R., Singer, J. & Westphal, M. (1969). Weight gain during pregnancy and prepregnancy weight: Association with birthweight of term gestation. Obstetrics and Gynecology, 33, 482-491.
- O'Driscoll, K., Meagher, D., MacDonald, D. & Geaghegan, F. (1981). Traumatic intracranial haemorrhage in firstborn infants and deliver with obstetric forceps. British Journal of Obstetrics and Gynaecology, 88, 577-581.
- Pasamanick, B. & Lilienfeld, A. M. (1955). Association of maternal and fetal factors with the development of mental deficiency. I. Abnormalities in the prenatal and paranatal periods. Journal of the American Medical Association, 159, 155-160.
- Petterson, L., Yonas, A. & Fisch, R. O. (1980). The development of blinking in response to impending collision in preterm, full term, and postterm infants. Infant Behavior and Development, 3, 155-165.
- Rickards, A. L., Ford, G. W., Kitchen, W. H., Doyle, L. W., Lissenden, J. V. & Kieth, C. G. (1987). Extremely-low-birthweight infants: neurological, psychological, growth

- and health status beyond five years of age. The Medical Journal of Australia, 147, 476-481.
- Rosenblith, J. F. (1992). In the Beginning: Development from Conception to Age Two. (Second Edition). Newbury Park, California: Sage Publications.
- Saxton, D. W. (1978). The behavior of infants whose mothers smoke in pregnancy. Early Human Development, 2, 363-369.
- Schulte, F. et al. (1977). The ontogeny of sensory perception in preterm infants. European Journal of Pediatrics, 126, 211-224.
- Segalowitz, M. (1993). Personal communication based on paper presented at the meeting of the International Neuroscience Society, Galveston, Texas.
- Sigman, M., Kopp, C. B., Littman, B. & Parmalee, A. H. (1977). Infant visual attentiveness in relation to birth condition. Developmental Psychology, 13, 431.
- Sigman, M. & Parmalee, A. H. (1974). Visual preferences of 4-month-old premature and full-term infants. Child Development, 45, 959-965.
- Simpson, J. W., Lawless, R. W. & Mitchell, A. C. (1975). Responsibility of obstetrician to the fetus II: Influence of pre-pregnancy weight and pregnancy weight gain on birthweight. Obstetrics and Gynecology, 45, 481-487.
- Smellie, W. (1772). Treatise on the Theory and Practice of Midwifery, Edition of 1772, Vol. I, p. 230.
- Stewart, A. L., Costello, A. M., Hamilton, P. A., Baudin, J., Townsend, J., Bradford, B. C. & Reynolds, E. O. R. (1989). Relationship between neurodevelopmental status of very preterm infants at one and four years. Developmental Medicine and

Child Neurology, 31, 756-765.

Teller, D. Y. & Bornstein, M. H. (1987). Infant color vision and color perception, in Handbook of Infant Perception, Volume I, From Sensation to Perception. P. Salapatek & L. Cohen (Eds.), pp 185-236. New York: Academic Press.

Towbin, A. (1970). Central nervous system damage in the human fetus and newborn infant. American Journal of Diseases of Children, 119, 529-542.

Vernon, M. (1967). Prematurity and deafness: The magnitude and nature of the problem among deaf children. Exceptional Children, 30, 289-298.

Wheeler, T. & Greene, K. (1975). Fetal heart rate monitoring during breech labour. British Journal of Obstetrics and Gynaecology, 82, 208-214.

Wigglesworth, J. S. (1984). The central nervous system, in Perinatal Pathology. (p. 243). Philadelphia: W. B. Saunders.