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## **The Evolution of Helplessness in the Human Infant and Its Significance for Pre- and Peri-Natal Psychology**

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**ABSTRACT:** As with most primates, optimal development in infancy proceeds with a high degree of intimacy and interaction between infants and caretakers. Human infants are less developed at birth than most primates because of selection for a greater percentage of brain growth to take place after birth than in utero. Reasons for delayed development of brain include the high degree of intimacy between maternal and fetal systems because of the hemochorial placenta; the upper limits to intrauterine brain development imposed by the maternal pelvis; and the advantage of having the brain develop in the more challenging environment outside the uterus. The impact of delayed development on the caretaker is reviewed, as are the effects of the quality of the neonatal environment on subsequent development of visual, locomotor, linguistic, and manipulative skills.

Cross-species comparisons have been used extensively in research on human infancy, most notably the work of the Harlows and their colleagues (Harlow, 1958; Harlow and Harlow, 1965; Harlow, Harlow, and Hansen, 1963) and Hinde and his colleagues (Hinde, 1974; Hinde and Simpson, 1975; Hinde and Spencer-Booth, 1971). Nonhuman primates are often cited as appropriate animal models for human development because of their close genetic and evolutionary relationship to our species. For the early neonatal period, however, nonhuman primates may not be suitable because of differences in the state of development of human infants relative to other higher primates. Primates typically give birth to precocial young which are able, within minutes of birth, to crawl along their mothers' abdomens and cling to their fur unaided. Human infants are far more altricial in some systems and

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lack the motor skills to cling to their mothers, even if suitable body hair and a grasping hind limb were available. This degree of altriciality sets limits and potentials for the developing human infant during the first few months of postnatal life. This paper will review the possible evolutionary events leading to selection for relative helplessness in the human infant and offer observations on the consequences of this state for perinatal behavior and development.

### COMPARISON OF HUMAN AND NONHUMAN NEONATES AT BIRTH

For the first few months of postnatal life, the human infant shares the growth pattern of other primate fetuses, not of other primate infants. Ashley Montagu called attention to this phenomenon in a 1961 article in which he referred to the first nine months of postnatal life for the human infant as "exerogestation" to distinguish them from the nine months from conception to birth, or "uterogestation." In his argument birth is merely the transition from one gestational stage to the other; it is not the end of gestation as is traditionally believed. Further, he argues that for the human infant, birth is analogous to that of marsupials: Clearly gestation is not completed for marsupials at the time they leave the uterus to continue development in the pouch.

Earlier, Portmann (1941, 1945, cited in Gould, 1977) had proposed that the human gestation period was actually 21 months and that we continued part of our development outside the womb, as "extra-embryonic embryos." The most obvious system that develops "embryologically" for the first few months of postnatal life is the neonatal brain. At birth, the human brain is about 25 per cent of adult size, measuring about 350 cm<sup>3</sup> (21 in<sup>3</sup>). By one year it will have more than doubled in size to approximately 800 cm<sup>3</sup>, and it is not until age three that the brain reaches 75 per cent of what its adult size will be. The rate of growth is much more typical of fetal development than of early neonatal rates when compared to other species. Rhesus macaque infants are born with about 70 per cent of adult size and chimpanzees with about 40 per cent. These species double their brain size by the end of the first year of postnatal life.

Other systems are also immature at birth. Liver enzymes, for example, appear several months after birth and gastric enzymes for digesting foods other than colostrum and milk do not develop for several

months (Crelin, 1973). The immunological and temperature-regulating systems do not complete development until the end of the first year of postnatal life. Ossification of the hands and feet of human infants at birth is equivalent to that seen in macaque fetuses at 18 weeks of gestation. The macaque is born at 24 weeks gestation with bone development that human infants will not have for several years (Schultz, 1949). Cranial plates are far less developed at birth in human infants compared with other primates.

For most developmental stages of life, the human duration is at least one-third to one-half longer than that of other primates. Harvey and Clutton-Brock (1985) provide the following figures: Age at sexual maturity for females is 10 years in chimpanzees, 7 in gorilla, and 16 in humans in pre-industrial societies; growth is completed at age 11 in chimpanzees and gorillas, but not until age 20 in humans; life span is approximately 40 years in the great apes and 70 years in humans. Based on this pattern, one would assume that gestation length would also be one third to one half longer for humans but such is not the case. Gestation averages 228 days in chimpanzees, 256 days in gorillas, and 267 days in humans. Extending this period by 6 to 9 months would bring human gestation more in line with other developmental stages.

It can be argued that human infants are "secondarily altricial" at birth based on these comparisons with other primate species. Human milk, like those of other primates, is very low in fats and proteins, typical of animals that are in constant contact with their infants and whose infants can nurse at any time throughout day or night. Offspring of species with this type of milk are typically precocial at birth, with sufficient motor development to maintain contact with the mother. Example species include most primates and members of the orders Perissodactyla (odd-toed ungulates) and Artiodactyla (even-toed ungulates).

Species in which females deliver altricial young which must be left behind while the mothers forage for food have milk high in fat and protein, sufficient to keep the infants satiated for two to eight hours, depending on the species. As noted above, human infants can be described as altricial in several developmental systems, but the milk available to them is more appropriate for precocial infants. It is likely, therefore, based on current understanding of the evolutionary history of the human species, that humans are descended from ancestors who gave birth to more precocial young. In other words, our primate ancestors, including the last common ancestor of monkeys, apes, and humans, were likely precocial at birth. Human infants can thus be con-

sidered altricial secondarily to their ancestors having passed through a stage of delivering precocial young.

Why are human infants so retarded in development relative to other primates? At least three reasons for the evolution of delayed maturation and greater helplessness of the human infant have been given: 1) the physiological advantage of delaying maturation of certain proteins until after delivery in a species characterized by close immunological intimacy of the maternal and fetal systems; 2) the upper limits to intrauterine brain development imposed by the maternal pelvis; and 3) the advantage of having the brain develop in the more challenging environment outside the uterus rather than in the presumed relatively unstimulating environment within the uterus.

### THE EFFECT OF THE PLACENTA ON ALTRICIALITY OF THE HUMAN INFANT

Most mammalian placentas can be categorized into four groups according to the number of layers between the maternal and fetal circulatory systems. For example, horses, donkeys, swine, lemurs, and lorises have epitheliochorial placentas with the maximum of six layers, three of maternal origin and three of fetal origin. Monkeys, apes, and humans have hemochorial placentas with three fetally-derived layers and no maternally-derived layers. The hemochorial placenta is more efficient in delivering oxygen to the developing fetal brain, which explains its advantage in the higher primates. In general, however, the fewer the number of layers between the maternal and fetal systems, the more likely that a fetus very different from the mother will be rejected. For example, horses and donkeys can interbreed and produce healthy, albeit sterile, offspring. Females of species with hemochorial placentas are not only unlikely to conceive and gestate heterospecific offspring, they often have difficulty carrying to term a fetus of their own species with even a few genetic differences from themselves. A familiar example in humans is the problem that arises when a fetus has blood group antigens (e.g., A, B, or Rh positive) that the mother lacks (e.g., O or Rh negative).

It can thus be argued that the type of placenta we have inherited places limits on the variability that can be tolerated between generations. In an evolutionary sense, however, there are circumstances under which greater genetic variability between generations would be advantageous. These advantages are particularly clear when a species

is evolving into a rapidly changing environment such as that proposed for human ancestral populations.

It should be noted that maternal immunological reaction to, and perhaps rejection of, the fetus occurs only for gene complexes that develop before birth. Any genotypic or phenotypic difference from the mother that does not develop until after birth will not trigger reaction in the maternal system. Goodman (1961) has suggested that delayed development of certain fetal and infant proteins represents a compromise between the advantages of close intimacy of the maternal and fetal systems and the advantages of variability between generations of a species evolving in a changing environment. One result of this delayed maturation of some proteins is greater immaturity and longer period of dependence of the human infant. An example of proteins with delayed development are the gamma globulins which help the infant fight infection. Since they do not develop until after birth, the newborn human infant is dependent on antibodies acquired from the mother during late pregnancy and early nursing. It is notable that the gamma globulins exhibit great variability within our species (Goodman, 1960).

### **LIMITS TO BRAIN DEVELOPMENT IMPOSED BY THE BIPEDAL PELVIS**

In the absence of modern surgical techniques, birth, by necessity, takes place through the maternal pelvis. This results in a tight squeeze for most primates whose neonates characteristically have large heads relative to maternal body size. It can be assumed, then, that difficult delivery was characteristic in the last common ancestor of chimpanzees and humans. This last common ancestor (approximately 5-6 million years ago) is presumed to have had the pelvis of a generalized quadruped (Walker and Teaford, 1989). The transition from this to the narrower bipedal pelvis of the earliest hominids (known as australopithecines) is the major evolutionary change that occurred with the origin of the line leading to modern humans, about five to six million years ago. The narrower bipedal pelvis meant that birth was an even greater challenge to the earliest hominids than it had been for their ancestors. Brain size in these hominids ranged from 380 to 650 cm<sup>3</sup> (Johanson and Edey, 1981; Day, 1986). The australopithecine pelvis could have allowed delivery of an infant with cranial capacity development similar to that of contemporary great apes (36-55%). This suggests that prenatal and postnatal brain growth patterns were similar

to those of other primates and that the infants were thus less helpless than are human infants today.

Martin (cited in Lewin, 1982) has suggested that the changes in pre- and postnatal brain growth patterns did not occur until less than two million years ago when adult cranial capacity began to increase in the hominid line. Cranial capacity of *Homo habilis* (1.9 to 1.6 million years ago) averaged about 700 cm<sup>3</sup> and their pelvises would have allowed the passage of an infant with cranial capacity of 300-350 cm<sup>3</sup>, about one half that of the adults. This is the maximum size that can be passed today, indicating that absolute fetal cranial size may not have changed significantly for the past two million years. But as adult brain size increased in the human lineage, this fetal brain size represented a smaller and smaller percentage of adult size until today, when we see that our infants are born with about one-quarter the brain size they will have as adults. Thus, it can be argued that delayed brain development and the resulting increasing helplessness of the human infant have occurred through a somewhat gradual process over the last two million years (Trevathan, 1987).

### THE ADVANTAGES OF DELAYED DEVELOPMENT OF THE HUMAN INFANT

Selection for fetuses whose heads were small enough to be delivered through their mothers' narrow bipedal pelvises is, in a sense, selection *against* infants with heads that are too large. Thus, the disadvantages of having brains too large are clear, but are there advantages to being born with relatively undeveloped brains? Portmann (cited in Gould, 1977) and others have argued that for an animal as dependent on learning as are humans, having most of brain development occur in the more stimulating environment outside the womb would be advantageous. These advantages become more clear when one examines particular parts of the brain that are developing rapidly in the first few months of postnatal life of the human infant.

Development of the visual and afferent systems begins before birth, occurs rapidly, and is completed at age 4 months (Bronson, 1982). Certainly vision is the most important means through which humans (and other primates) acquire nonlinguistic information about their environment. Development of visual acuity seems directly dependent on stimulation during the period of most rapid growth (Blakemore and Cooper, 1970), suggesting that optimal visual functioning would not

develop in infants exposed only to the visually unstimulating uterus. Immediately after birth, the normal infant begins visual searching, a process that facilitates further development of that system. As I will discuss later, the image presented by the mother's face, with its contrasting dark and light areas, is optimal for developing mature visual skills.

For a species so dependent on language as are humans, the importance of optimal auditory development cannot be overrated. The language centers in the brain develop in the first 3 years of life as the brain is undergoing its rapid expansion. Like visual development, auditory stimulation is important and the first few years of life have been called critical ones for the development of language in the child.

Although most scholars have emphasized the development of audition and vision in early infancy, it is likely that taste, touch, and olfaction are maturing in similar ways and that early experience is also important for optimal development of those senses. (Turkewitz, 1979; Schaal, 1988).

### BIRTH OF THE ALTRICIAL HUMAN INFANT

No matter how numerous the advantages of being born at a relatively undeveloped state, newborn human infants would not survive their birth or the first few days and months of postnatal life without assistance from highly motivated caretakers. As noted previously, the more precocious monkey infant can pull itself from the birth canal once its arms and head are free, and can crawl up the mother's abdomen and search for a nipple with little or no assistance. The monkey mother typically licks her newborn infant dry and then consumes the placenta while paying only a little attention to her infant. Subsequently, although she grooms and interacts with her infant frequently, nursing and clinging to her body are largely up to the infant. This more laissez-faire attitude toward newborn infants would greatly decrease survival of altricial human infants, and a different pattern of caretaking has been selectively favored over the course of hominid evolution.

Human females typically give birth in the company and with the assistance of other women. I have previously argued that this behavior may have begun as far in the past as two million years, coinciding with selection for increasing brain size in the genus *Homo* (Trevathan, 1987). The human infant usually emerges facing away from the mother (the monkey emerges facing the mother) and having another

person assist in wiping mucus from the mouth and nose, checking for umbilical cord constriction at the neck, and bringing the infant around to its mother's arms is arguably preferable to the mother doing this alone (Trevathan, 1988). The human infant is not capable of pulling itself from the birth canal and finding the breast on its own.

When early postpartum interaction between mother and infant is not interrupted, typical maternal behaviors include rubbing and massaging the infant's body, talking to it in a high-pitched voice, gazing into its eyes, and holding it on the left side of the body (Trevathan, 1987). These behaviors serve to calm the infant, regulate breathing, and contribute to stabilization following what is likely an abrupt transition from the uterus to the outside world. All of these behaviors thus contribute to immediate survival of the newborn infant. Within an hour, the infant usually begins nursing, a behavior that, in the past at least, contributed to the survival of the mother, in that stimulation of the breast results in release of oxytocin, which, in turn, inhibits uterine bleeding.

Thus, the advantages of being born when the brain and related systems are somewhat undeveloped have accrued to our species only because hominid mothers for the past two million years have behaved in predictable and necessary ways at the time of birth.

### SUBSEQUENT DEVELOPMENT OF THE ALTRICIAL INFANT

The impact of altriciality on the caretaker at the time of birth has been noted, but perhaps even more significant is the effect of continued helplessness over several months and years of infancy. (The monkey infant is relatively independent of its mother by age two and the chimpanzee by age four.) This helpless state continues to affect caretaker behavior, learning potential, and infant survival. The significance of exposure to environmental stimuli has been pointed out, and since the infant is dependent on the caretaker to provide the stimuli or the opportunity for experience with the environment, the caretaker's behavior is particularly important in determining the course of development in auditory, visual, and central nervous system functioning.

One factor that may have impact on development is sleeping patterns. Obviously infants learn more when they are awake than when they are sleeping. Since infants seem to spend much of the early days of postnatal life sleeping, it may appear that concern for early exposure



to environmental stimuli is unwarranted. This, however, may be as much due to cultural expectation as to neonatal biology. Wolff (1959) describes six behavioral patterns observed in newborn infants. These include a period of alert inactivity ("quiet alert state"), drowsiness, alert activity, crying, and two patterns observed during sleep. The quiet alert state is the one in which most learning is presumed to take place, as the infant is wide awake, searching with its eyes, fixing eye contact on objects and people, following voices and faces. Although this state is short and infrequent in the first several days and weeks after birth, several studies have reported a long period in this state immediately after birth. This may be due in part to the sympathoadrenal surge that occurs in the infant during birth (Laughlin, 1989). Presumably much learning takes place during this time of adjustment to an entirely new environment. This quiet alert period immediately after birth coincides with a period of high arousal in the mother, so it is undoubtedly advantageous for optimal mother-infant bonding. Obviously the duration and significance of this long period of wakefulness in the infant and the parallel state in the mother are dependent on the amount of medication that the mother had during labor and delivery and the amount of additional stress that the mother and infant experience immediately postpartum.

Much of fetal and neonatal behavior seems to be regulated by subcortical areas in the brain. Mimicking human evolutionary history, the subcortical parts of the brain develop first and are relatively mature at birth, whereas the neocortex is not fully functioning at birth (Bronson, 1982). The transition from subcortical control of behavior to cortical control begins at some point prior to or soon after birth, and further development of the neocortex seems to depend on experience. For example, minutes after birth, a human neonate can stand supporting its own weight, and will move its legs in an alternating walking movement known as "primary walking" (Zelazo, Zelazo, and Kolb, 1972). If placed on its stomach, a newborn infant will attempt to crawl. Both of these behaviors are believed to be under subcortical control. They wane soon after birth, and cannot be elicited again until the infant is several months older. Zelazo et al. (1972) report, however, that if infants are continuously challenged to "walk" for the first several days of postnatal life, some of the behaviors can be prolonged indefinitely. Furthermore, if the infant is "walked" regularly, independent walking develops earlier. This suggests that our concept of the onset of walking at one year may be as much based on expectation and child-rearing practices as on species-typical development patterns.

Konner (1973) observes that !Kung infants begin walking at an earlier age than do Western infants, in part due to parental expectations and treatment of neonates. The !Kung infant is carried upright in a sling against the mother's body. Placing, walking, and crawling movements enable the infant to readjust itself at will and may enable it to avoid suffocation. In other words, these early movements are adaptive for some infants today and were undoubtedly adaptive in the past.

Konner (1977) has also observed that !Kung infants typically spend a great deal more time in an upright position compared with their EuroAmerican counterparts. He notes research that shows that the upright position enhances cognitive development, increases attention span, and decreases stress. Konner and Thoman (1970) conclude from their research that the upright position and vestibular stimulation contribute to development of visual acuity, especially in the first few months of postnatal life when, as noted, development of the visual system is occurring.

Early breathing is largely under subcortical control. It has been suggested that when breathing is challenged by breastfeeding, infants may more easily make the transition from subcortical to cortical control of breathing, a process which occurs between 2 and 4 months of postnatal life. Rovee-Collier and Lipsitt (1982) suggest that this may have implications for Sudden Infant Death Syndrome (SIDS) in that surmounting the challenge offered by trying to maintain breathing while breastfeeding may better prepare the infant to meet later challenges to breathing such as might occur with slight colds or sniffles. Bottlefeeding is relatively easy and may deprive infants of the experiences that prepare them for appropriate responses to later interference with respiration (Stratton, 1982).

### MAINTAINING PROXIMITY IN AN ALTRICIAL SPECIES

As noted above, the quality of human milk, the need for warmth, and numerous other factors made it necessary in the past (and in most cultures today) for very young infants to be in more or less constant contact with their mothers. For most primate species, maintaining this proximity is somewhat under control of their relatively precocious young who are able to cling to their mothers, even while they are moving rapidly. Human infants lack the motor ability to maintain physical contact with their mothers, and thus must rely on more distal

behaviors, noted by John Bowlby (1969), that maintain attachment. These behaviors include crying, smiling, following with the eyes, and suckling. They elicit caretaking responses in the mother, attract her to the infant, and result in physical contact. Physical contact usually leads to feeding and serves to calm the infant, all of which contribute to conserving energy in the potentially compromised neonatal system.

Although crying is a universal behavior in human infants, the routine daily crying that we have learned to expect may not have been characteristic of healthy infants in the past, just as it is apparently not typical of healthy infants today, in cultures where normal caretaking includes maintaining constant contact between mothers and infants. Konner (1972) has noted that in the United States today we consider "on demand" breastfeeding to mean responding immediately to an infant cry by offering the breast. !Kung women rarely let their infants get so hungry that they cry for food because the mother anticipates hunger in the child against her body by reading such infant cues as moving, gurgling, fretting, and changing breathing rhythm. The need to cry for comfort is also alleviated by the fact that the infant is in physical contact with someone, primarily the mother, for approximately 90 per cent of the first few months of its life (Eaton, Shostak, and Konner, 1988). Crying is energetically expensive, has a negative impact on others in the vicinity, interferes with parent-infant interaction, and probably reduces opportunities for learning. It is reasonable to assume that crying occurred with low frequency in our ancestors, just as it is rare in modern nonhuman primates.

Although infant smiles in the first three months of life may be fleeting and variable, they have profound effects on caretakers and help to focus a mother's attention on her newborn child. The so-called "social smile," coordinated with vision and hearing, does not appear until about three months of age, and is tied to cerebral development (Trevathan, 1985).

At birth, the human neonate is able to focus on objects approximately 12 inches away, roughly the distance from the mother's eyes to her breast when she looks at her infant during breastfeeding (Brazelton, Scholl and Robey, 1966). It is well known that infants prefer to look at a human face, a preference that has been demonstrated in infants less than 10 minutes old (Goren, Sarty, and Wu, 1975). Stratton (1983) notes that the human face, with its contrasts of light and dark and its movements, is the perfect stimulus for maximal neural firing rate (Haith, 1980), and it is a stimulus that is most likely to be present during the neonatal period. Thus, development of the neonatal visual

system is optimized by the presence of the most predicted image in the neonatal environment, the mother's face (Stratton, 1983).

Two patterns of suckling have been described for the human infant: nutritive suckling and nonnutritive suckling (Wolff, 1968). The first is continuous suckling-while-breathing, common to all mammals, whereas the second pattern, characterized by alternating bursts and pauses, may be unique to humans. Kaye (1977) argues that this behavior prepares the infant for the "taking of turns" that is necessary in communication, and that by responding to the pause, as a mother often does by gently shaking her breast or the infant, she is approximating the dialogue that will characterize later verbal interaction. Nonnutritive suckling also has a calming effect on infants which, in turn, probably enhances mother-infant interaction and increases the time during which learning can take place.

### CONCLUSIONS AND IMPLICATIONS FOR PRE- AND PERINATAL DEVELOPMENT

As Laughlin notes in his introduction to this issue (see also, Laughlin, 1989), there is a great deal of variation in the attitudes that people of different cultures have toward newborn infants. These attitudes may, in turn, affect early infant behavior and development. For example, if it is a cultural assumption that infants are passive and learn little in the early weeks of postnatal life, chances are these infants will not be stimulated as much by their caretakers, and, as a consequence, they *will* learn little in the first weeks of life. The fact that Oriental, African, and South American infants are more precocious soon after birth than are infants of European origin may be due as much to cultural variation in treatment of infants as to biological or genetic differences, as Laughlin (1989) notes.

Optimal development in human infancy, as in most primates, proceeds with a high degree of intimacy and interaction between infants and caretakers. Human infants are less developed at birth because of selection for a greater percentage of brain growth to occur after birth than in utero. This means that most of the responsibility for maintaining proximity and interaction is up to the caretaker, although the infant has a wide array of behaviors that serve to attract the caretaker and invite interaction. The human infant is primed to learn about its environment from the first minutes of postnatal life, and during the first several months will lay the foundations for subsequent develop-

ment of locomotor, linguistic, visual, auditory, and manipulative skills. Development of these skills occurs while the brain is undergoing rapid growth and when the potential for learning is great. Despite the plasticity of the human infant, the quality of the environment provided by the caretakers and the attitude toward infants held by members of a particular culture understandably have a major impact on this development.

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