Environmental Influences on Human Brain Growth and Development

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Abstract: None available.

Full Text: Headnote ABSTRACT: In a study designed to create an enriched environment for prenates by minimizing environmental stressors and substituting a positive, stimulating milieu, we designed a program that would reduce maternal stress with visualization and relaxation exercises, encourage mother-child bonding through prenatal communication and interaction exercises, and pleasantly stimulate prenatal auditory, tactile, visual and vestibular processes. Results from 150 pregnant women in the enrichment program compared to 100 pregnant women in a control group showed that infant head circumference as an analog of brain development in the enriched group was significantly larger than that of the control group. Moreover, most dimensions on the Denver assessment scales showed earlier acquisition of gross and fine motor skills, language, and personal-social development by the enriched group compared to sample norms of Bangkok children. ABOUT THIS PAPER: Dr. Panthuraamphorn's research in creating positive and stimulating prenatal environments spans a number of studies, starting with the pilot study reprinted here. This new paper represents his most ambitious project to date, undertaken with colleagues Dawiep Dookchitra and Manit Sanmaneechai who were co-researchers in a 1995 study focusing on auditory stimulation. We have included this paper on brain growth because, first, brain growth has been an important factor in human evolution. Since all brains are constructed inside a mother's womb, a well-constructed brain says that the uterine environment was very favorable because research consistently indicates that unfavorable conditions compromise all parts of the brain. Therefore, it makes a great personal difference, as well as a difference to society, if brains are constructed well or poorly. A second reason is that brain growth has been associated with some programs of prenatal stimulation, a surprising fact, if true. In the first Thai study (Panthuraamphorn, 1993), the experimental babies were superior in both height and in head size compared to control babies, yet the 1995 Thai study mentioned above featuring auditory stimulation alone found no significant difference in the 24 stimulated babies when compared to Bangkok norms. In the Caracas study reprinted in this issue, stimulated babies did have larger head sizes but the difference was not statistically significant. This was a tantalizing discovery since all subjects in that experiment lived in poverty. What if extra attentions from parents could overcome the disadvantages of poverty? To date, virtually all of the formal experiments in prenatal enrichment have shown significant advances in a variety of intellectual functions, reflecting better brain development if not bigger heads. If it were to be proved that enriched prenatal parent-child communication and bonding does enlarge brains, it would confirm a developmental principle increasingly indicated by both human and animal studies that brains, even during construction, do actually grow and thrive by being put to good use. INTRODUCTION Studies of environmental and maternal stress (e.g., Schell, 1981; Stott, 1973) indicate that fetal development may be negatively influenced by factors that are increasingly common in industrialized countries. Socioeconomic pressures on family life may lead to less mother-and-child bonding as women struggle to balance activities and have less time for traditional roles. Such factors may affect physical, emotional, social and cognitive growth. Potentially offsetting this negative potential, recent research indicates that enriching the fetal environment can promote development along several dimensions. For instance, in animal studies from the University of California at Berkeley (Diamond, 1987) pregnant rats inhabiting an enriched environment produced offspring whose brains had a thicker cortex, with 10% more cholinesterase and 10% more glial cells than a control group. Human studies of prenatal stimulation (e.g., Panthuraamphorn, 1995, 1994, 1993, 1991) suggest that enriched environments produce developmentally advanced infants. We decided to combine these two strands of research into a single study that would create an enriched environment for the unborn child that would minimize environmental stressors and substitute a positive, enriched environment by: reducing maternal stress with visualization and relaxation programs; encouraging mother-child bonding through prenatal communication and interaction exercises; introducing a positive, enriched environment by pleasantly stimulating the unborn's auditory, tactile, visual and vestibular processes. In this way, we hoped to explore whether the enriched environment could influence development, and if so, along what dimensions; and whether it could influence brain growth in humans, similar to Diamond's study (1991). METHODOLOGY To follow up and reconfirm results in our earlier study of 24 infants (Panthuraamphorn, 1993), who showed good performance on physical, social and emotional growth, we enlisted 150 pregnant women in a prenatal enrichment program to evaluate the effect of this new environment on their infants' brain growth and development. They were matched with 100 pregnant women in a control group matched for socioeconomic and health factors. There were two parts to our enrichment program design. The first part (Program 1) was designed to minimize stress factors, encourage bonding between the mother and the unborn child, and stimulate endorphins. The program consisted of relaxation techniques, fear and anxiety relief techniques, visualization, breathing exercises, massage, affirmations, interaction exercises and an endorphin releasing program. Relaxation techniques were employed to counter real and imagined hazards, previous traumas, fears of ill or deformed children, personal immaturity, fears of lost beauty, etc. that might negatively influence the development of the unborn child. The program provided six relaxation exercises to dimmish anxiety that were to be practiced from the first trimester until delivery. Creative visualization was used to induce a state of mind and body relaxation to reduce the fear of childbirth and promote a positive view of birth, bonding and motherhood. These exercises were designed to be done daily. Abdominal massage was used to give the mother and the fetus physical ease and relaxation because tension affects the fetus in utero, producing chemical changes within the fetal body. Massage of other parts of the body was used to improve circulation and relieve tension. Massage was recommended 2-3 times per week. Interaction exercises were designed to promote the early involvement of the father in the pregnancy. The endorphin-releasing technique stimulated the mother's tactile, auditory, visual, gustatory, olfactory and vestibular pathways to promote the release of these hormones to support the physical and emotional growth of the unborn child. We suggested a sequence of bathing, sitting in a rocking chair, relaxing, looking at a beautiful picture, and listening to classical Thai music. Participating mothers practiced these techniques every day beginning at 12 weeks gestation age until birth. The second part of the program (Program 2) was organized around the concept of minimizing negative environmental stimuli and replacing them with positive stimuli through a learning process designed to engage fetal visual, auditory, tactile, and vestibular systems. For example, mothers were taught to talk, pat, play music, rock and communicate with their unborn children. Each activity was introduced and practiced at the different gestational weeks corresponding to the fetal capacity to perceive the stimulus, respond to it, and learn. Table 2 shows the rate of compliance with both programs by mothers enrolled in the enriched group. Note that the majority of mothers engaged in all practices more than 3-4 days per week.

Table 1
Sample Characteristics and Obstetric Factors

	Enriched group (N = 150) mean ± SD	*Control group (N = 100) mean ± SD*	*t*	*p*
Maternal age in years	29.9 ± 4.5	28.8 ± 3.8	1.50	0.13
Gravid (number of pregnancies)	1.3 ± 0.6	1.2 ± 1.0	0.49	0.62
Education*	1.3 ± 0.5	1.4 ± 0.5	0.85	0.39
Economic status**	1.5 ± 0.5	1.5 ± 0.5	0.07	0.94
Type of delivery†	1.3 ± 0.5	1.25 ± 0.45	0.43	0.67
Amniotic fluid††	1.2 ± 0.4	1.08 ± 0.29	0.59	0.56
Term/Preterm‡	1.1 ± 0.3	1.1 ± 0.3	0.46	0.65

*1 = College graduate, 2 = Undergraduate.
**1 = >30,000B, 2 = <30,000B (incomes ranged from 10–50,000B).
†1 = Normal labor, 2 = Cesarean section.
††1 = Clear, 2 = Meconium stain.
‡1 = Term, 2 = Preterm (born earlier than 37 weeks g.a.).

Participants were monitored for their frequency of practice. At birth and 6 months later, infants in the enriched and control groups were evaluated. We recorded the infants' weight and head circumference as an outcome measurement of brain growth. The Denver developmental test was used to assess levels of social, language, emotional, and motor functioning. RESULTS There were no significant differences in maternal and obstetric factors, as displayed in Table 1. The average weight of the enriched infants at birth and 6 months were 3.24 and 8.17 kg respectively compared to 3.16 and 8.13 kg for the control infants. The enriched group, therefore, was heavier, but not at a statistically significant level as shown in Table 3. The analysis for head circumference measured at birth revealed a significant stimulation effect (t = 2, p = 0.047), and it was even more significant as measured six months after birth (t = 3.61, p = 0.0004). These results indicate that the enriched infants show greater brain growth than the controls.

Table 2
Frequency of Compliance by Mothers in the Enriched Group

Practice times/week	*Program 1*	*Program 2*			
		Auditory	*Tactile*	*Visual*	*Vestibular*
Every day	6.5%	11.3%	19.5%	20.0%	16.5%
5–6	22.8%	35.2%	36.9%	22.4%	19.2%
3–4	54.3%	37.5%	33.6%	31.7%	35.2%
>3–4	83.6%	84.0%	90.0%	74.1%	70.9%
1–2	16.3%	15.9%	9.7%	17.7%	17.9%
No practice	0.0%	0.0%	0.0%	8.2%	11.2%

We also evaluated infants in the enriched group for developmental differences using the Denver assessment compared to normative data for Bangkok infants, as shown in the following four figures. Numbers in the figures represent quartiles. That is, the first number represents the age when 25% of the subjects exhibit the behavior being assessed; the second number represents the median; the third, when 75% of the sample demonstrate it; and the fourth number, when 90% of the population can do it. The data in Figure 1 show that the enriched infants consistently demonstrated social behaviors earlier than the sample norms for Bangkok infants. For example, the 25% of the enriched environment infants started smiling responsively at 0.6 months, and 90% of them could smile responsively by 2.2 months compared to the general Bangkok infants, one quarter of whom were responsively smiling at 1.0 months, and 90% by 5.6 months.

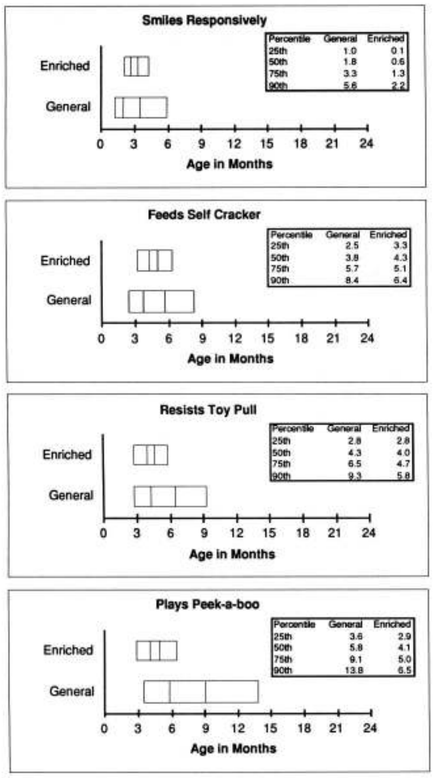
Table 3

Weight and Head Circumference Measurements at Birth and Six Months of Age in Both Groups

	Enriched group (N = 150) mean ± SD	*Control group (N = 100) mean ± SD*	*t*	*p*
Weight at birth (kg)	3.24 ± 0.48	3.16 ± 0.38	1.14	0.26
Weight at 6 months (kg)	8.17 ± 0.87	8.13 ± 0.85	0.26	0.79
Head circumference at birth (cm)	34.65 ± 1.49	34.2 ± 1.25	2.00	0.047
Head circumference at 6 months (cm)	43.85 ± 1.68	43.05 ± 1.08	3.61	0.0004

Figure 1

Personal-Social Development of Enriched Group Compared to Sample Norms of Bangkok Infants



The frequency of practice in the gross motor sector for enriched mothers, such as rocking in a rocking chair, was only 70.9% (more than 3-4 times a week), less than any other stimulation activity participants practiced. Nevertheless, enriched infants demonstrated earlier motor control than sample Bangkok infant norms in terms of holding the head up, rolling over, sitting without support, standing holding onto support, pulling the self up to stand, and standing momentarily. This suggests that enriched infants have faster motor development than a normal population. In Figure 3 depicting assessments of fine motor development, the enriched infants followed an object through 180° of motion, placed their hands together, transferred a cube from hand to hand, and reached for an object earlier than the sample norms for Bangkok children. The time differences between the two groups on placing the hands together and reaching for an object is not very marked, but the enriched group's ability to follow an object and transfer a cube from hand to hand occurred significantly earlier. Language development in the enriched group also was considerably advanced compared to the sample norms for Bangkok children. Enriched infants could vocalize, laugh, turn toward a voice, and name or call their parents earlier, as shown in Figure 4. DISCUSSION In this study, head circumference was used as an outcome measurement of brain growth. Infants in the enriched group showed significantly larger head circumference compared to the control group matched for demographic and obstetrical factors. The findings suggest that this effect may be a result of the enrichment program the mothers practiced. We surmise that fetal brain size increased owing to growth in the density of dendrites in response to stimulation of the fetus's auditory, tactile, visual and vestibular senses, as was demonstrated in earlier animal studies. There was a tendency for the enriched group to show greater weight gain than the control group, but not at a statistically significant level. Weight gain is difficult to evaluate as a result of the program because it may be affected by other factors, especially dietary intake during pregnancy.

Figure 2

Gross Motor Development of Enriched Group Compared to Sample Norms of Bangkok Infants

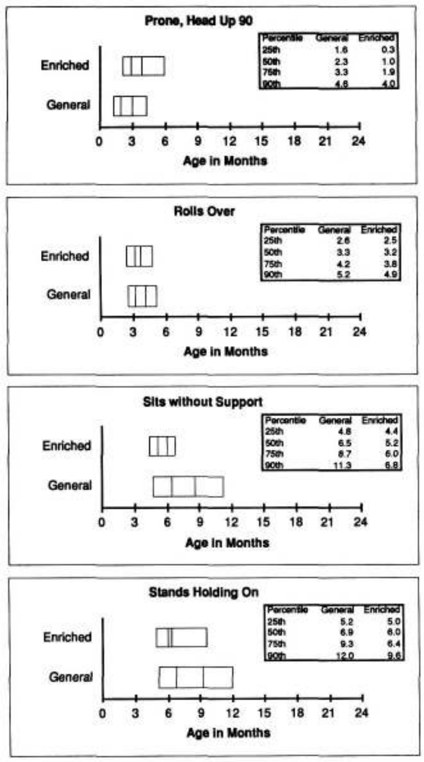


Figure 2

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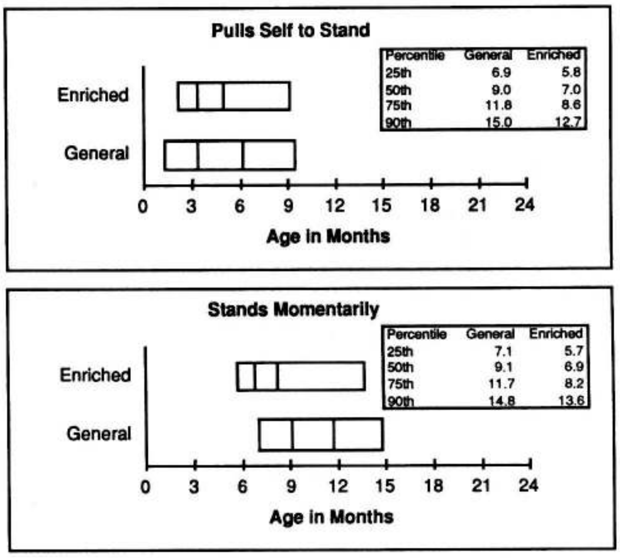


The enriched infants could engage in positive social interactions, such as smiling and laughing earlier than sample norms of Bangkok children. It may be that the mother's endorphins are stimulated and released by the program of interaction, massage, relaxation and visualization during pregnancy, creating a positive emotional environment for the fetus that carries over after birth. Motor development in the enriched group was, on the whole, significantly earlier than that for the sample norms of Bangkok infants. The enriched group's gross motor skills (except for rolling over) were significantly in advance of the Bangkok sample, which could be the effect of vestibular stimulation. The mother's use of a rocking chair in the enriched program may be responsible for improvement in infant motor tone and balance, and audiovisual stimulation may be a contributing factor to motor skills as well. Lifting the head, sitting without support, standing holding on, pulling the self to stand and standing momentarily all occurred earlier in the enriched group. Some fine motor skills, in particular following an object and transferring a cube from hand to hand, showed up earlier in the enriched infants compared to the norm for Bangkok infants. We hypothesize that visual stimulation in the enrichment program provided by the use of a search light may stimulate optical neural cells and pathways, producing a faster learning process and enhancing motor development. There was no significant difference in the time enriched babies started placing the hands together and reaching for an object compared to norms for Bangkok children.

Figure 3

Fine Motor Development of Enriched Group Compared to Sample Norms of Bangkok Infants

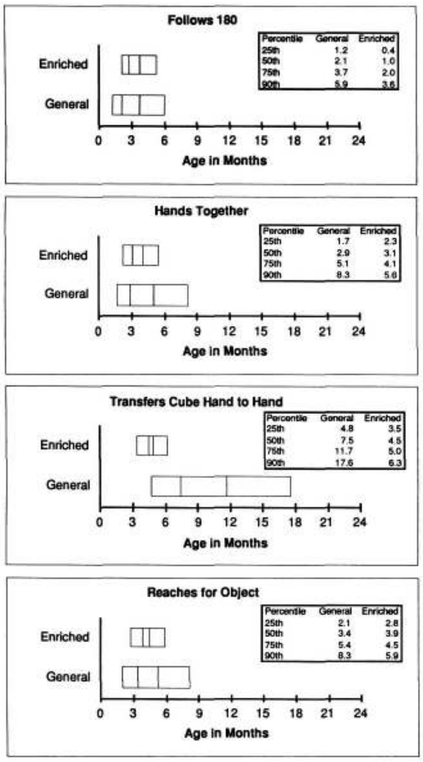
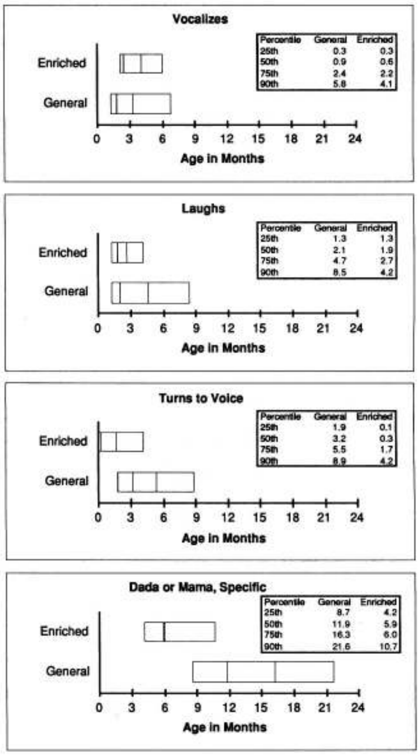


Figure 4

Language Development of Enriched Group Compared to Sample Norms of Bangkok Infants



Prenatal auditory enrichment may benefit social development. Previous studies (Panthuraamphorn, 1995; Thurman &Langness, 1984) indicated that music heard during the prenatal period may be the foundation for language development and vocalization. In this study, personal-social and language evaluation showed that enriched infants can smile, vocalize, laugh, turn toward a voice, and call "mama", "dada" earlier than a sample norm of Bangkok infants. In conclusion, the results of this study suggest that prenatal enrichment programs can enhance fetal brain growth and promote social, motor, and language development. Owing to the positive findings of this study, we recommend that the enriched environmental program we developed should be considered for routine prenatal care units to promote brain growth and development for future generations. References REFERENCES Diamond, M. (1987). Mother's enriched environment alters brains of unborn rats. Brain / Mind Bulletin 12(7), 1-5. Panthuraamphorn, C. (1991). The effect of a designed prenatal enrichment program on growth and development of children. 5th International Congress on Pre- and Perinatal Psychology. Atlanta, GA. Panthuraamphorn, C. (1993). Prenatal stimulation program. In T. Blum (Ed.), Prenatal perception, learning and bonding (pp. 187-220). Hong Kong: Leonardo. Panthuraamphorn, C. (1994). How to maximize human potential at birth. Pre- and Perinatal Psychology Journal 9(2), 117-126. Panthuraamphorn, C., Dookchitra, D. &Sanmaneechai, M. (1995). Prenatal auditory learning, technique of enrichment and outcome. International Journal of Prenatal and Perinatal Psychology and Medicine 7(4), 437-445. Schell, L. M. (1981). Environmental noise and human prenatal growth. American Journal of Physical Anthropology 56, 63-70. Stott, D. H. (1973). Follow-up study from birth of the effects of prenatal stresses. Developmental Medicine in Child Neurology 15, 770-787. Thurman, L. &Langness, A. (1984). Heart songs: Infants and parents sharing music. Denver, CO: Music Study Service. AuthorAffiliation Chairat Panthuraamphorn, M.D., Dawiep Dookchitra, M.D., and Manit Sanmaneechai, M.D, AuthorAffiliation Address correspondence to Chairat Panthuraamphorn <better@asiaaccess.net.th>.

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