Prenatal Stress and Handedness Among Offspring

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Publication info: Pre- and Peri-natal Psychology Journal 6. 2 (Winter 1991): 135-144.

Abstract: None available.

Full Text: Headnote ABSTRACT: Stressful experiences recalled by 270 mothers beginning a year prior to pregnancy through to the end of pregnancy were compared for right, left, and mixed handed offspring of both sexes. For the male offspring, mothers of left handers recalled significantly more severe stress throughout pregnancy than mothers of either right or mixed handers. For the female offspring, no significant differences were found. Results were interpreted as consistent with the view that stress hormones secreted by the mother during pregnancy can significantly affect the hemispheric functioning of the neocortex of offspring. Stress hormones-such as adrenaline, Cortisol, corticosterone-produced and secreted by mother mammals during pregnancy have been shown to reach the fetus(es) via the placenta (Zarrow, Philpott, &Denenberg, 1970). It has been well established that stress hormones interfere temporarily with the synthesis and release of sex hormones, particularly testosterone (Davidson, Smith, &Levine, 1978; Harding, 1981; Ward &Weisz, 1984; Anderson, Rhees, &Fleming, 1985; Delahant &Mellsop, 1987). Several lines of evidence indicate that prenatal exposure to sex hormones, especially testosterone, are involved in organizing the hemispheres of the neocortex (Dawson, 1977; Geschwind, 1984; Diamond, 1988). In particular, exposing the brain to high levels of testosterone (and/or its metabolite, estradiol) during fetal development seems to shift the normal tendency for the left hemisphere to dominate in higher thought and fine motor control at least partially to the right hemisphere (Levy &Levy, 1978; Diamond, 1984). This would help to explain why, in humans, males have been often observed to be somewhat more left or mixed handed than females (e.g., Annett, 1970; Oldfield, 1971; Teng, et al., 1976; Le Roux, 1979; Lewkowicz &Turkewitz, 1982). The above lines of evidence lead one to suspect that maternal stress during pregnancy (prenatal stress) might alter handedness (and possibly other aspects of sidedness) of offspring. In support of this hypothesis, a recent study of rats showed that male offspring of mothers subjected to stress during pregnancy were unusually prone to lead with the left, instead of their right, paw (Fleming, Anderson, Rhees, Kinghorn, &Bakaitis, 1986). Two other studies of rats have found that prenatal stress alters the rate of dopamine turnover in various regions of the right hemisphere Of offspring in ways that are likely to reduce the normal degree of left cerebral dominance (Friede &Weinstock, 1987, 1988). The present study was undertaken to determine if stress experienced by human mothers during pregnancy would be related to the handedness of their offspring in adulthood. METHOD As part of a larger study primarily designed to discover whether or not prenatal stress was associated with variations in sexual orientation, 270 mothers and their offspring were recruited to complete anonymous questionnaires which could be matched according to a common code number appearing on both the mother's and offspring's forms (Ellis, Ames, Peckham, &Burke, 1988). Because the primary aim was to identify prenatal factors related to sexual orientation of offspring, homosexual and bisexual offspring were purposely over-sampled, constituting approximately 30% of the male offspring and 10% of the female offspring (Ellis, Burke, &Ames, 1987). Mothers ranged in age from 36 to 77 years, with a mean of 51.5 (SD = 8.6). Offspring ranged in age from 19 to 50, with a mean of 25.5 (SD = 6.5). Nearly all of the mother/offspring pairs (98%) were Caucasian, and 56% of the offspring listed north-midwestern states as the place of birth, with the remainder scattered throughout the rest of the United States. Mothers responded to a 6-page questionnaire, three pages of which were devoted to inquiries about emotional stress during all three trimesters of pregnancy as well as during the year preceding pregnancy. Collectively, these 21 months are referred to as the "reference period." The mother's questionnaire not only asked about the timing and form of any stress they may have had, but were also asked to assign a subjective weight-ranging from 1

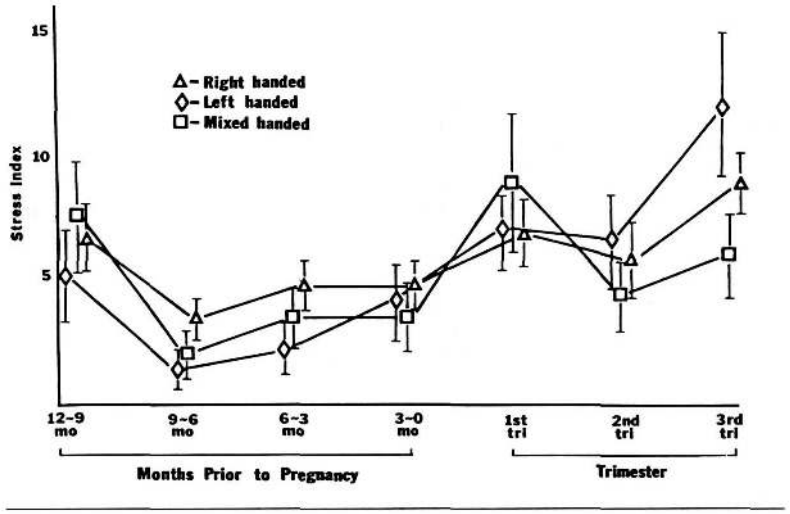
("not at all severe") to 4 ("extremely severe")-to each incidence of stress the mothers experienced during the reference period. To help them recall stressful events they may have had throughout the reference period, mothers were presented with the following list of 31 potentially stressful events: death of the spouse; divorce from spouse; marital separation from spouse; father of the child serving in war zone; death of a close relative; personal injury or illness; injury of loved one; loss of a job by self or spouse; you got married; marital reconciliation; deterioration in health of a relative; sexual problems; gain of a new family member; change in financial well being; contending with a troublesome child; death of a close friend; change of job by you or spouse; increasing arguments with spouse or other close adult; assumption of major new debt; foreclosure on a loan; major change in religion; quarrels with in-laws or neighbors; mental illness in the family; alcoholism or drug problems among those close to you; change in work hours; change in residence; legal difficulties; witness a major accident or crime; a significant local community tragedy; and a significant world or national tragedy. This list was an elaboration of one first used by Dorner, Schenk, Schmiedel, and Ahrens (1983) in an exploratory study of human prenatal stress and homosexual preferences. Mothers were instructed to identify if any of the 31 stress incidences had been experienced by them during each 3-month time frame throughout the 21-month reference period. They were also asked to report how severe they recalled each stressful event being in terms of the appropriate 4-point severity code. To derive the unweighted stress index, we summed the total number of stress incidences reported by mothers in each 3-month time frame. For the weighted stress index, we multiplied each stress incidence times the severity code assigned to it by the mother and summed the total in each 3-month time frame. Turning to the offspring's questionnaire, handedness was measured by asking subjects to indicate which hand they used to perform the following nine tasks: writing, drawing a picture, throwing a ball, using a scissors, brushing teeth, cutting with a knife, eating with a spoon, twisting off the lid of a jar, striking a match, and poking thread through the eye of a needle. To each of these nine items, subjects could respond (1) nearly always left, (2) usually left, (3) roughly even, (4) usually right, and (5) nearly always right. Scores ranged from 9 (indicating extremely left handed) to 45 (indicating extremely right-handed). This measure is similar to several others which treat handedness as a continuous variable (e.g., Hicks, Duesk, Larsen, Williams, * Pelligrini, 1980; Coren, Searleman, &Porac, 1982). As expected, the majority of offspring reported being extremely right handed. Specifically, 45 (42%) of the males and 96 (59%) of the females reported using their right hand "almost always" for all nine manual tasks (i.e., they scored 45 out of 45 on the handedness scale). In order to have a meaningful number of left handed and mixed handed subjects among the offspring for comparison, we designated left and mixed handed subjects as follows: The remaining 62 males and 67 females were arranged in order with regard to their handedness score (ranging from 9 to 44). Then, we designated offspring with scores at or above the median as "mixed handers," and those with scores below the median as "left handers." This left us with the following number of mixed and left handers: Mixed handers (those scoring 39 to 44)-31 males and 39 females Left handers (those scoring 9 to 38)-31 males and 28 females RESULTS Table 1 presents an ANOVA for male and female offspring both for the unweighted and weighted stress index. The independent variable was stress to the mother during pregnancy, and the dependent variable was the three handedness categories. As one can see, there were significant differences between the handedness groups in the case of males, but not in the case of females. In the case of the unweighted prenatal stress, the differences were significant at the 0.5 level, and, in the case of the weighted prenatal stress, the differences were significant at the .002 level. With regard to the weighted stress (where the greatest differences exist among the males), a graphic picture of differences reflected in Table 1 are presented in Fig. 1 and Fig. 2 along with the differences in maternal stress in the year prior to pregnancy. As one can see in Fig. 1, no consistent differences between mothers of right, left, or mixed handers are apparent in the case of female offspring. Possibly, however, in the third trimester, mothers of left handers are reporting higher levels of stress than the other mothers, especially those with mixed handed offspring.

TABLE 1
One-way ANOVA for variations in unweighted and weighted stress by mothers during pregnancy according to the handedness of their offspring in adulthood.

Source	*df*	*SS*	*MS*	*F Value*	*p*
Unweighted Prenatal Stress and Female Offspring Handedness					
Group	19	9.3723	.4933	.82	.69
1st tri	7	2.2065		.52	.82
2nd tri	5	2.6992		.89	.49
3rd tri	7	4.4665		1.05	.40
Error	142	85.9178	.6051		
Weighted Prenatal Stress and Female Offspring Handedness					
Group	41	30.6822	.7483	1.40	.09
1st tri	15	9.0360		1.13	.34
2nd tri	10	9.0370		1.69	.09
3rd tri	16	12.6156		1.47	.12
Error	115	61.5725	.5354		
Unweighted Prenatal Stress and Male Offspring Handedness					
Group	17	18.2757	1.0750	1.72	.05
1st tri	5	6.3663		2.03	.08
2nd tri	6	3.3723		.90	.50
3rd tri	6	8.5371		2.27	.04
Error	88	55.1299	.6265		
Weighted Prenatal Stress and Male Offspring Handedness					
Group	35	38.2504	1.0929	2.23	.002
1st tri	10	11.4121		2.32	.02
2nd tri	11	11.3245		2.10	.03
3rd tri	14	15.5138		2.26	.02
Error	69	33.8829	.4911		

As shown in Fig. 2, consistent differences were found for mothers of male offspring. Beginning 3-0 months prior to pregnancy, and continuing throughout pregnancy, mothers of left handers reported over twice as severe of stress on average as did mothers of either right or mixed handed males.

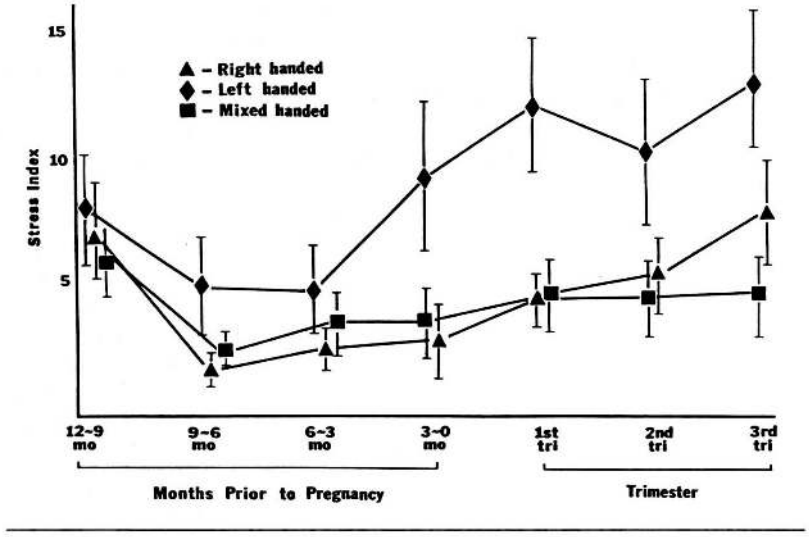
FIGURE 1
Average number of prenatal stress incidences weighted according to severity as perceived by mothers, beginning 12 months prior to pregnancy through to the point of birth, for female offspring according to the handedness of the offspring. (Vertical lines represent standard error of the mean.)



DISCUSSION While tentative, the present findings add support to the view that hemispheric functioning among

males may be fundamentally altered during gestation (Geschwind, 1984), and that prenatal stress (at least when it is severe), can affect the course of how the hemispheres are functionally organized (Fleming, Anderson, Rhees, Kinghorn, &Bakaitis, 1986; Fride &Weinstock, 1987). Even though we expected to find such evidence, we were surprised by the precise pattern of what was found. For example, among male fetuses, there is evidence that stress hormones secreted by the mother inhibits production of testosterone by the fetus (Ellis &Ames, 1987; Ellis, 1990). If testosterone is being inhibited by prenatal stress, and prenatal stress tends to diminish the dominance of the left hemisphere relative to the right hemisphere Geschwind, 1984), one would expect that mothers of left handers would have reported less stress during pregnancy than mothers of right handers or mixed handers. This is exactly the opposite of what was found. If the present results are correct, some important additional factors in the underlying causes of hemispheric differentiation of the brain involved in handedness determination remain to be elucidated.

FIGURE 2
Average number of prenatal stress incidences weighted according to severity as perceived by mothers, beginning 12 months prior to pregnancy through to the point of birth, for male offspring according to the handedness of the offspring. (Vertical lines represent standard error of the mean.)



Even though several results from this study achieved high levels of statistical significance, they must be considered extremely tentative and in need of replication. Among the reasons are the following: First, the independent variable (prenatal stress during each trimester of pregnancy) was determined retrospectively based on accounts given by mothers recalling events which occurred to them on average nearly 25 years earlier. While such methodological procedures have been utilized in other studies (Bakan, Dibb &Reed, 1973; Dorner, et al., 1983; Ellis, et al., 1988), the reliability with which mothers may recall such events have been called into question (Chamberlain &Johnstone, 1975; Schwartz, 1988, 1990). In defense of the basic methodology as reliable, one should keep in mind that mothers were not simply asked if they recalled having experienced stress during or before pregnancy. Instead, they were presented with a lengthy list of potentially stressful events, and asked to indicate if any of these events had occurred to them during pregnancy or up to a year prior to pregnancy. In addition, the mothers were asked to specify the three-month interval in which the specific event had occurred, and to estimate how severe each stressful experience had been on a four-point scale. A second shortcoming of this preliminary study surrounded the relatively small sample size. The procedure we used to maximize the proportion of the offspring who were non-righthanded, and to virtually equalize the number of "left" and "mixed" handers would not be comparable to the procedures used in most other studies of handedness. Nevertheless, it is worth noting that, despite the fairly arbitrary nature of the way

we designated left, mixed, and right handers, the results were very significant statistically. We tried several other arbitrary cut-off points for offspring handedness, and found the basic patterns shown in Figs. 1 and 2 essentially unchanged, although the levels of statistical significance were generally diminished. Third, the proportion of male and female offspring in the sample who were homosexual and bisexual was greater than would be found in a general population (Ellis, et al., 1987). It is interesting to note that one recent study found nonright-handedness may be more common among nonheterosexuals then heterosexuals, at least in males (Lindesay, 1987), although another study failed to find significant differences (Rosenstein &Bigler, 1987). The present study found no significant relationships between sexual orientation and handedness. Fourth, no controls were introduced for other potentially confounding variables. Among the most likely variables that might interact with prenatal stress in affecting handedness are various perinatal events such as premature birthing, prolonged labor, and hypoxia. It is conceivable that these factors are directly responsible for deviations from exclusive right handedness (for reviews see Searleman, Porac, &Coren, 1989; Bakan, 1990), and that prenatal stress is merely a frequent accompaniment of birth complications. However, the reverse of this scenario is also a possibility that is in need of research attention. References REFERENCES Anderson, D.K., Rhees, R.W., and Fleming, D.E. (1985). Effects of prenatal stress on differentiation of the sexually dimorphic nucleus of the preoptic area (SDN-POA) of the rat brain. Brain Research, 332, 113-118. Annett, M. (1985). Left, Right, Hand and Brain: The Right Shift Theory. London: Lawrence Erlbaum. Annett, M. (1988). Comments on Lindesay: Laterality shift in homosexual men. Neuropsychologia, 26, 341-343. Bakan, P., Dibb, G., &Reed, P. (1973). Handedness and birth stress. Neuropsychologic, 11, 363-366. Bakan, P. (1990). Nonright-handedness and the continuum of reproductive casualty. In S. Coren (Ed.), Left-Handedness: Behavioral Implications and Anomalies (pp. 31-74). Amsterdam: Elsevier. Barlow, S.M., Knight, A. and Sullivan, F.M. (1978). Delay in postnatal growth and development of offspring produced by maternal restraint stress during pregnancy in the rat. Teratology, 18, 211-218. Chamberlain, G. &Johnstone, F.D. (1975). Reliability of the history. Lancet, 1, 103. Coren, S., Searleman, A., &Porac, C. (1982). The effects of specific birth stressors on four indexes of lateral preferences. Canadian Journal of Psychology, 36, 478-487. Davidson, J.M., Smith, E.R., Levine, S. (1978a). Testosterone. In H. Ursine, E. Baade, &S. Levine (eds.), Psychobiohgy of Stress: A Study of Coping Men (pp. 57-62). New York, Academic Press. Dawson, J.L. (1977). An anthropological perspective on the evolution and lateralization of the brain. Annals of the New York Academy of Sciences, 299, 424-447. Delahunt, J.W. and G. Mellsop, G. (1987). Hormone changes in stress. Stress Medicine, 3, 123-134. Diamond, M.C. (1984). Age, sex, and environmental influences. In N. Geschwind, and A. MM. Galaburda (Eds.) Cerebral Dominance: The Biological Foundations (pp. 134-146). Cambridge, Mass.: Harvard University Press. Diamond, M.C. (1988). Enriching Heredity. New York: Free Press. Dorner, G., Schenk, B., Schmiedel, B. &Ahrens, L. (1983). Stressful events in prenatal life of bi- and homosexual men. Experimental and Clinical Endocrinology, 81, 83-87. Ellis, L. (1990). Left- and mixed-handedness and criminality: Explanations for a probable relationship. In S. Coren (Ed.), Left-Handedness: Behavioral implications and anomalies (pp. 485-507). Amsterdam: North-Holland. Ellis, L. and Ames, M.A. (1987). Neurohormonal functioning and sexual orientation: A theory of homosexuality-heterosexuality. Psychological Bulletin, 101, 233-258. Ellis, L., Ames, M.A., Peckham, W., and Burke, D. (1988). Sexual orientation of human offspring may be altered by severe maternal stress during pregnancy. Journal of Sex Research, 25, 152-157. Ellis, L., Burke, D. and Ames, M.A. (1987). Sexual orientation as a continuous variable: A comparison between the sexes. Archives of Sexual Behavior, 16, 523-529. Fleming, D.E., Anderson, R.H., Rhees, R.W., Kinghorn, E. and Bakaitis, J. (1986). Effects of prenatal stress on sexually dimorphic asymmetries in the cerebral cortex of the male rat. Brain Research Bulletin, 16, 395-398. Fride, E. and Weinstock, M. (1987). Increased interhemispheric coupling of the dopamine systems induced by prenatal stress. Brain Research Bulletin, 18, 457-461. Fried, E. Weinstock, M. (1988). Prenatal stress increases anxiety related behavior and cerebral lateralization of dopamine activity. Life Sciences, 42, 1059-1065. Geschwind, N. (1984). The biology of cerebral dominance: implications for cognition. Cognition, 17, 193-208. Harding, C.F. (1981). Social modulation

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Publication title: Pre- and Peri-natal Psychology Journal

Volume: 6

Issue: 2

Pages: 135-144

Number of pages: 10

Publication year: 1991

Publication date: Winter 1991

Year: 1991

Publisher: Association for Pre&Perinatal Psychology and Health

Place of publication: New York

Country of publication: United States

Journal subject: Medical Sciences--Obstetrics And Gynecology, Psychology, Birth Control

ISSN: 08833095

Source type: Scholarly Journals

Language of publication: English

Document type: General Information

ProQuest document ID: 198777684

Document URL: http://search.proquest.com/docview/198777684?accountid=36557

Last updated: 2010-06-06

Database: ProQuest Public Health
