Mathematics, sex hormones, and brain function

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Benbow's proposal that prenatal testosterone exposure may in part determine extremely high mathematical reasoning ability is suggestive, but estradiol exposure seems a better bet (Nyborg 1979; 1983), because it has more direct organizational and activational effects on sensitive brain tissues (see Toran-Allerand 1986).

Estradiol may actually explain many of the relations among sex hormones, brain growth, spatial ability, and mathematics in humans. Thus, women with Turner's syndrome (Turner 1938) are deficient in sex hormones and have severe problems in spatial ability tasks and mathematics (e.g., Nielsen et al. 1977). However, Turner women who have received about 1 year of cyclic estrogen/gestagen treatment perform at the same level as their age-matched sisters on various tests for spatial ability as well as in mathematics (Nyborg & Nielsen 1981). These and other findings have led me to propose (Nyborg 1979; 1983; 1984; 1986) a curvilinear model for the effects of estradiol concentrations on body, brain, and spatial ability development as illustrated in Figure 1. According to this model, normal females (E-H) typically overshoot the range of estradiol values for the full expression of spatial ability at puberty. This explains the common female teenage regression in spatial ability and mathematical achievement (Nyborg 1983). A tilt in the sex hormone balance toward testosterone will slightly masculinize the female body and keep the brain concentration of estradiol within the range for the optimal expression of spatial ability. In this way, the model explains why late maturing, androgynous females tend to show higher spatial ability than do their more feminized counterparts. Normal males (A-D) undershoot the optimal range at puberty. A tilt toward testosterone will further masculinize the body and depress the expression of spatial ability (for details, see Nyborg 1983). Moderate estrogenization will feminize the body and lead to the full expression of spatial ability. This could explain why spatial ability tends to be higher in androgynous men than in very masculine men (e.g., Maccoby & Jacklin 1974). It has further been found that women show high spatial ability during low estrogen phases of the menstrual cycle, and low spatial ability during high estrogen phases (see Nyborg 1983). My model has since been elaborated to incorporate covariant intellectual and personality development and is now referred to as the general trait covariance androgen/estrogen (GTC-A/E) model (Nyborg 1984; 1987; submitted).

The GTC-A/E model allows for testable predictions about the sexual development of mathematically eminent people. These can, for example, be expected to show a moderate surge in sex-related gonadal steroid plasma concentrations at puberty, and a low degree of secondary sexual differentiation. The male mathematician will be either tall and slender or pyknic, will have a low muscle content and accordingly show decreased muscular strength, will be long-lived, and will have been a sissy as a child. The GTC-A/E model further predicts that the female mathematician will have a low body-fat ratio, will be tall, slender, and strong, and will reflect a childhood history of tomboyism. Mathematically eminent people go into puberty late and show a prolonged period of brain development. They are typically first-born, come from a family with few children, and have, themselves, few offspring (in particular, few dizygotic twins). They show reduced physical aggressiveness, high behavioral restraint, introversion, and prefer abstractions and objects to people. They prefer controlled political development and appreciate a formal to a loose social organization of society (Nyborg 1987). Let me, therefore, suggest that Benbow initiate a person-specific search for the mathematically eminent, unrestrained he-man and for the opulent, very fertile, extroverted female mathematician in her large populations. The finding of more than a few such "Black Swans" would falsify my GTC-A/E model.

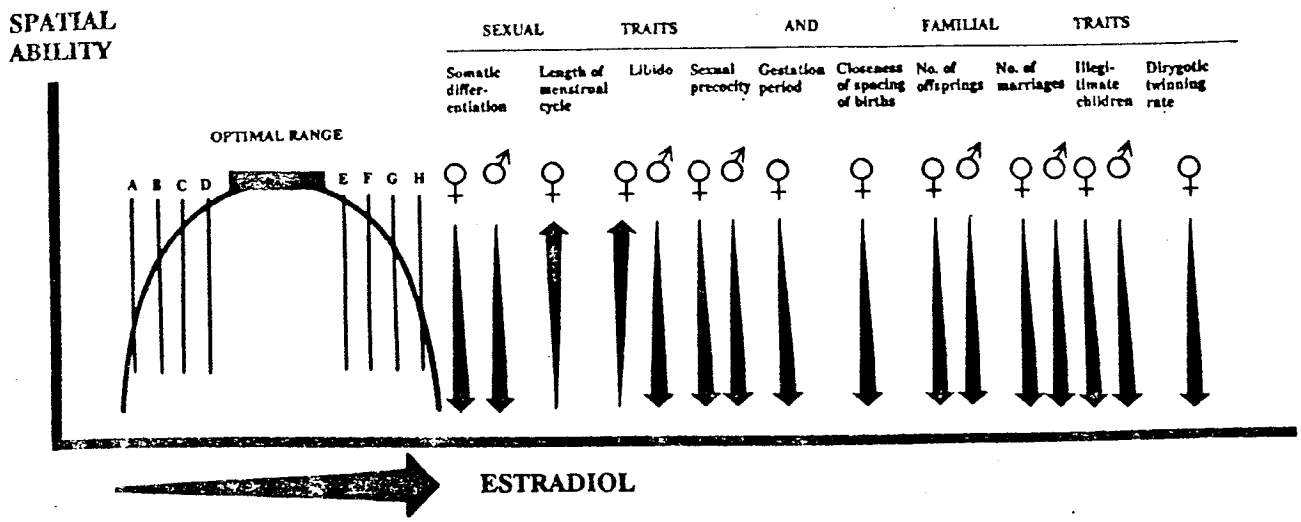

Figure 1 (Nyborg). The General Trait Covariance-Androgen/Estrogen (GTC-A/E) balance model for the effects of variation in gonadal hormones on body, brain, and behavioral development in masculinized (A-D) and feminized (E-H) individuals (from Nyborg 1987; for explanation, see text).

References

Hampson, E., & Kimura, D. (1987). Reciprocal effects of hormonal fluctuations on human motor and perceptuo-spatial skills. Research Bulletin 656, Department of Psychology, University of Western Ontario, London, Canada.

Maccoby, E. E., & Jacklin, C. N. (1974). The psychology of sex differences. Stanford University Press, Stanford.

Nielsen, J., Nyborg, H., & Dahl, G. (1977). Turner's syndrome. A psychiatric-psychological study of 45 women with Turner's syndrome, compared with their sisters and women with normal karyotype, growth retardation, and primary amenorrhoea. Aarhus : Acta Jutlandica, Medicine Series 21. Aarhus University Press.

Nyborg, H. (1979). Sex chromosome abnormalities and cognitive performance. V. Female sex hormones and discontinuous cognitive development. Paper presented in the symposium on "Cognitive studies" at the fifth biennial meeting of the International Society for the Study of Behaviour Development, Lund, Sweden., June 25-29, Abstract guide p. 35.

Nyborg, H. (1983). Spatial ability in men and women: Review and new theory. Advances in Behavioural Research and

Therapy, 5, 89-140.

Nyborg, H. (1984). Performance and intelligence in hormonally-different groups. In: G. J. de Vries, J. P. C. de Bruin, H. B. M Uylings, and M. A. Corner (Eds.) Sex differences in the brain: The relation between structure and function. Progress in Brain Research, Vol. 61. Amsterdam: Elsevier Biomedical Press, 491-508.

Nyborg, H. (1986). Sex chromosomes, sex hormones, and developmental disturbances: In search of a model. Paper presented at the 152nd Annual National Meeting of the American Association for the Advancement of Science, Philadelphia, 25-30 May.

Nyborg, H. (1987a). Principles of sex hormonal regulation of body, brain and behavioral development. (submitted).

Nyborg, H. (1987b). Covariant trait development across races, and within individuals. Paper presented at the third meeting of The International Society for the Study of Individual Differences, Toronto, Canada, 18-22 June.

Nyborg, H., & Nielsen, J. (1981). Sex hormone treatment and spatial ability in women with Turner's syndrome. In: W Schmid and J. Nielsen (Eds.) Human Behavior and Genetics. Amsterdam: Elsevier/North-Holland, 167-182.

Rosenthal, K. & Kimura, D. (1987). Hormonal influences on cognitive ability patterns. Research Bulletin 653,Department of Psychology, University of Western Ontario,

London, Canada.

Toran-Allerand, D. (1986). Sexual differentiation of the brain. In: W. T. Greenough & J. M. Juraska (Eds.). Developmental Neuropsychobiology. New York: Academic Press, 175-211.

Turner, H. (1938). A syndrome of infantilism, congenital webbed neck, and cubitus valgus. Endocrinology, 23, 566-574.