



Sexing the baby: Part 1 – What do we really know about sex differentiation in the first three years of life?

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ABSTRACT

The most common paradigm used to analyze health differences between men and women, is to divide the body from the social environment. In such a model, the bodily contribution and the social contribution add up to 100%. A few health science researchers offer more sophisticated approaches. None, however, offer an intensive study of the first several years of life in order to offer a model which integrates biology and culture in a fashion that demonstrates the productive processes by which gender itself emerges. In this article, we identify the earliest known sex-related biological and behavioral differences in young infants, toddlers and their parents and indicate how these might relate to health and disease. We frame these differences using unifying concepts from the study of neuroplasticity and dynamic systems theory.

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Introduction

Men's and women's health problems and their health care needs sometimes differ. Similarly boys and girls face somewhat different developmental challenges. Many differences stem, self-evidently, from different reproductive anatomies and physiologies. More surprising have been non-reproductive differences, for example differing manifestations and timing of heart disease, differing rates of immune disease and varying patterns of mental illness (Institute of Medicine, 2001). Indeed, such sex-related variation presents a theoretical challenge to the health sciences. On the one hand it seems to call into question the idea that there is a universal physiology that can be understood *via* a universal norm. On the other, it seems to suggest an unlikely conclusion — that there are two possibly non-overlapping normals, one for women and one for men. Either model has important implications for health maintenance and disease prevention and treatment.

How then might we theorize the relationships between sex, gender, human physiology and health (both mental and physical)? The most common paradigm divides the body from the social environment, apportioning disparities between these two sources. In such a model, the bodily contribution and the social contribution always add up to 100% (Bierman, 2007; Society for Women's Health Research). In contrast, Bird and Rieker emphasize the view that biological differences can result from social causes (Bird & Rieker,

1999). Within the context of epidemiological health research, Krieger considers embodiment as a multi-leveled process, arguing that good theory and research practice ought to integrate body and psyche within specific social, historical and ecological contexts (Krieger, 2005). Her central claim, with which we quite agree, is that bodies offer us information about the conditions in which they grow and develop. A third mode of analysis—the Life Course Approach (Kuh & Hardy, 2002; Kuh, Power, & Bartley, 1997)—has much in common with Krieger's models and with the dynamic systems approaches we champion (Fausto-Sterling, 2000, 2003, 2005, 2008; Fausto-Sterling & García Coll, 2006; Fausto-Sterling, García Coll, & Lamarre, 2011; Jimenez-Robbins, Ngnoumen, Ahl, Schmidt, Boghossian, Toth et al., 2009; Sung et al., 2010).

To develop dynamic approaches to embodiment, including the body's relationship to sex and to gendered social milieu, we need a starting point and a theory that can guide us as development proceeds. To this end we frame current knowledge about sex-related development in the first three years of life in terms of dynamic systems, an approach which emphasizes process-oriented, dynamic accounts of the body. Our framework integrates biology and culture in a fashion that has the potential to demonstrate the productive processes by which gender itself emerges and through which we can understand how seemingly sex-based differences in health are really due to the dynamic integration of biology and culture.

Researchers have produced a significant body of work on early-appearing sex-related behavioral differences (Hines & Collaer, 1993; Maccoby, 1998; Martin, Ruble, & Szkrybalo, 2002; D. N.

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Ruble & Martin, 1998; Diane N. Ruble, Martin, & Berenbaum, 2006). Some have parlayed these early differences into explanations of sex-related mental health differences, especially the differing rates of autism and ADD in boys and girls (Simon Baron-Cohen & Hammer, 1997; S. Baron-Cohen, Knickmeyer, & Belmonte, 2005). As with the study of health disparities, in the field of behavioral sex-related differences the predominant operating models – biological predisposition from neural and hormonal events during fetal development *versus* postnatal cognitive and social learning – have led to different types of experimentation and thus different and poorly connected bodies of knowledge. Although researchers on each side of the ontological divide acknowledge the importance of the other point of view, often relying on a poorly defined “interaction” term to link the two bodies of knowledge, such acknowledgment does not explain the emergence of sex-related differences in the early years. Here, we examine what we do and do not know about sex-related differences in biology and behavior from the prenatal period into the third postnatal year. Since researchers in this field often relate their findings to disparities in mental health, a careful analysis of the developmental baselines is crucial for critically assessing causes of mental health disparities. In leaning on perspectives adapted from dynamic systems theory we render visible, features of existing knowledge that we currently fail to notice and provide the study of gender and health with a grounding from which to develop better health-related knowledge (Spencer et al., 2006).

We present our findings in the following order: (1) what we know about behavioral differences between boys and girls in the first three years of life, (2) what we know about biological differences, (3) what evidence links biological differences to behavioral differences, (4) what we know about gender-related differences in behaviors from adult caregivers, and (5) the possible relationship of such behaviors to emergent sex-related differences in infants and toddlers. We limited our literature review to *the prenatal period through age three*, choosing the somewhat arbitrary cut-off point of 36 months because by that time there are several well-established sex-related differences. Our goal is to establish a time line for *emergence of difference*, which means starting before a phenomenon of interest is measurable in order to follow its appearance over time. Where possible we calculated effect sizes for reported differences using the online statistical calculators prepared by Lee A. Becker and available online at <http://www.uccs.edu/~lbecker/psy590/escalc3.htm> as well as the computer program *The Effect Size Generator* (Deville, 2004). Often the magnitude of differences starts out small in the face of large individual variability, but with age may become more established.

Most of the material we used to identify studies of sex differences in young children was obtained from searches of *PsychINFO* and *Academic Search Premier*. Initially we used the key terms *human-sex-differences*, and subsequently used a variety of other terms to narrow the search. We limited our review to articles appearing since 1950s. We also examined current child development textbooks to learn what were viewed as established sex differences and sought out the original works cited (or alluded to) in these texts. Several studies were also obtained from the reference lists of such fundamental works as *The Psychology of Sex Differences* (Maccoby & Jacklin, 1974), *The Two Sexes* (Maccoby, 1998) and *Gender, Nature and Nurture* (Lippa, 2002).

We excluded studies if they used only parent-reported measures of children's behavior (except in measures of communicative behavior), reasoning that parents' reports may be influenced by their expectations or assumptions (Seifer, Sameroff, Barrett, & Krafchuk, 1994). For the same methodological reasons, we would have liked to exclude studies in which the experimenters or observers are not blind to infant sex. However, blind studies are not

a standard practice in this field. Yet this early work includes some of the most often cited sources and is critical to any review of the literature and we thus felt we could not exclude it. Many heavily cited studies had not been replicated. While we initially intended only to include studies that had been replicated twice or more, this so severely limited our data that we eventually chose to include even those studies with no replications. We included findings showing a main effect of subject sex with the relationship significant at the level of $p < .05$. When possible, we presented the means as given in the original work.

We also studied meta-analyses (e.g. Hyde & Linn, 1988; Leaper, Anderson, & Sanders, 1998; Lytton & Romney, 1991) but did not include them in our data tables. Similarly, some studies revealed an interaction effect between sex and some other variable (e.g., birth order); while these are of interest, for the sake of clarity, we have not displayed them in our tables unless main effects of sex were reported. Furthermore, many reports present data on children at a range of ages (e.g. 2–5 year olds); unless means and/or statistics were given for children 36 months old and younger, we have not included these reports.

What behaviors show sex differences in infants and toddlers?

Activity levels

Recent meta-analyses of infancy, have found a small but significant tendency for boys to be more active than girls (effect sizes ranging from .12 to .29) (D. W. Campbell & Eaton, 1999; Eaton & Enns, 1986). Reviewing studies of preschoolers (aged 12–72 months) Eaton and Enns (1986) found a moderate effect size ($d = .44$), suggesting that activity level differences between boys and girls might grow over time. We graphed the effect sizes *versus* age listed by Campbell & Eaton, and found that in neonates the size of the sex-related difference is small (about 80% group overlap), but effect sizes decline to near zero at 4 months of age before increasing to somewhat larger sizes (75% group overlap) by the end of the first year of infancy (Fig. 1).

The idea that the motor systems of boys and girls develop differently (with boys at birth being less able to control motor function while later they seem to engage in more active motor coordinated play) is based on the above data and also on data from adults that suggest men engage in more physically active and risky behavior than women. Some link early, prenatally determined differences in motor activity to differential mortality in young men due to accidents and suicide (Pinker, 2008). It seems likely that a number of systems (for example, motor and sensory development rates, birth size, intermodal neural connectivity, prenatal stresses, birth trauma) underlie motor activity. The decline in magnitude of group difference by four months could result from a postnatal catch-up in which the bodies of individuals born with greater motor activity levels become better able to manage and control their activity. We presume that the early nurturing practices (swaddling, holding, etc.) contribute to this equalization. Perhaps after four months new sub-systems emerge as a result of nurturing practices that differentiate between male and female infants. Such speculation requires testing, but our main point here is that without examining the developmental dynamics of emerging difference we might miss these possible mechanisms altogether.

Toy preference

Preference for sex-typed toys is present by age three years (O'Brien & Huston, 1985; O'Brien, Huston, & Risley, 1983) but may first be noted as early as 10 months. Preference differences are absent at three months (A. Campbell, Shirley, Heywood, & Crook,

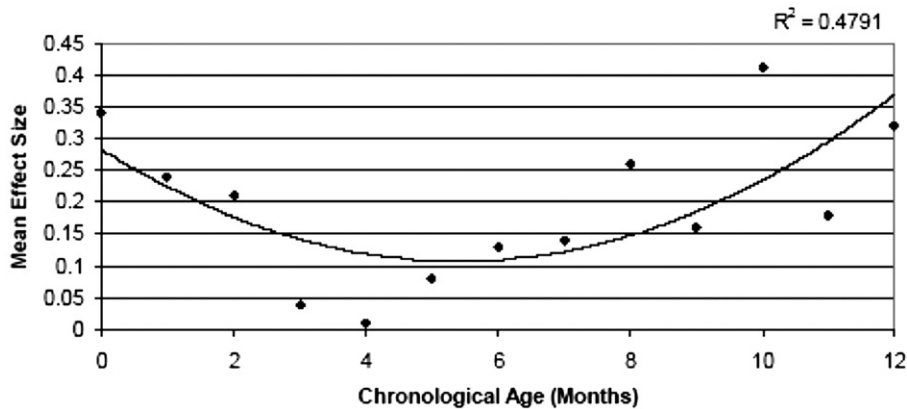


Fig. 1. Mean effect sizes for sex-related differences in activity level, from data in Campbell and Eaton (1999).

2000). Boys may develop toy preferences earlier than girls (O'Brien & Huston, 1985) (but see Blakemore, LaRue, & Olejnik (1979)). At younger ages, the effect sizes of group differences are moderate and variable, but by age three they have become large and stable. In general, girls play more with dolls, interact more often with their caregivers and display gender-stereotyped activities during play (i.e. play in the kitchen area). Boys play more with toys considered appropriate for boys (i.e. mechanical) (Lowe, 1975). For a full list and analysis of Toy Preference studies see Table 1, Supplementary data. Finally, Zosuls et al. found that increased verbal gender labeling ability significantly predicted increases in gender-typed play, suggesting that gender knowledge may influence gender typing even before age two (Zosuls et al., 2009).

Rheingold and Cook counted the differential availability of toys in boys' and girls' bedrooms from birth through five years of age (Rheingold & Cook, 1975). The extremity of some of their findings is striking. For example, the number of vehicular toys summed over all ages was 375 for boys compared to only 17 for girls. We suggest that early differential visual and tactile familiarity may train the brain and peripheral nervous system to prefer one toy type over another. To observe the dynamic development of toy preference in the first months of life we need to combine additional, detailed longitudinal studies, that track events in the home with an analysis of the neural basis of object preference. Such observations would let us evaluate claims that connect prenatal androgen exposure to adult neurological diseases such as tic-related disorders, which are alleged to be connected to pathologies of brain masculinization and associated with variation in gendered play patterns in childhood (Evardone, Alexander, & Morey, 2008). More generally, balancing gender-stereotyped play patterns could alter development in a way that might improve future health outcomes for both sexes (Eliot, 2009).

Vocalization

Differently developed capacities for speech and language are commonly linked later in life to sex differences in recovery outcomes following stroke or other brain damage (see discussion in Fausto-Sterling (1992)). More salient for children is the higher frequency of dyslexia in boys compared to girls. Some conceptualize this disorder as a static difference, originating, perhaps from genes and/or prenatal hormone exposures; to evaluate such a model for dyslexia we need to understand the developmental dynamics of sex-related differences in speech and vocalization (Eliot, 2009; Galaburda, 2005; Galaburda, LoTurco, Ramus, Fitch, & Rosen, 2006). Galaburda et al. (2006) for example, suggest that in animal models used to study of genes linked to dyslexia sex

differences may be linked to sex differences in neural plasticity. We would argue that studying such differences (if they are confirmed for humans) in the context of sex-related developmental differences in language exposure would provide dynamic models of dyslexia that might account for possible sex-related differences in frequency and suggest pathways for treatment.

Sex differences in vocalization are uncertain before six months (Brundin, Roedholm, & Larsson, 1988; Gunnar & Donahue, 1980; Lewis, 1969). Their significance has also been disputed for children aged 2–5 as well as older children and adults (Hyde & Linn, 1988). However, more than 15 studies demonstrate that after 6 months, girls outperformed boys in many aspects of language production. For the younger infants, effect sizes were small to moderate, but trended toward large as the children reached 20–30 months (group overlap ranged from 94% in infants to 36% on some studies of children in their 2nd and 3rd years), suggesting that initially small and variable sex-related differences in vocalization gradually solidify into consistent and increasingly large differences starting at about 6 months of age (Sung et al., 2010). For a full analysis of the vocalization studies see Table 2, Supplementary data. And finally, whether one considers the existence of sex differences in vocalization to be non-existent, large or somewhere in between, belief in such differences plays a role in the development of theories about autism and dyslexia.

Sensory system behaviors

A number of unreplicated studies suggest sex-related sensory differences in newborns and infants. There are reports that female neonates are more sensitive to changes in olfactory stimuli (Balogh & Porter, 1986; Makin & Porter, 1989), more sensitive to sweet taste, more engaged in oral behavior (Korner, 1973; Nisbett & Gurwitz, 1970) or more responsive to tactile stimulation (Bell & Costello, 1964; Lipsitt & Levy, 1959). Additional reports include higher rates of skin conductance (Weller & Bell, 1965), shorter latency EEG responses (Engel & Benson, 1968), more precise auditory localization responses (Muir, Clifton, & Clarkson, 1989), earlier binocular function (Gwiazda, Bauer, & Held, 1989) and higher and earlier rates of habituation in response to smaller visual changes (Caron & Caron, 1969; Creighton, 1984; Friedman, Bruno, & Vietze, 1974) in girls. Sex differences favoring earlier response times for girls' to habituation to a vibrotactile response have been reported as early as 25 weeks of gestation (Leader, Baillie, Martin, & Vermeulen, 1982).

A similarly sparse literature reports sex-related differences in cochlear development and auditory processing in newborns (Sininger, Cone-Wesson, & Abdala, 1998; Stuart & Yang, 2001;

Vento, Durrant, Sabo, & Boston, 2004). Although these differences could be interpreted as congenital, data from humans (Putzar, Goerendt, Lange, Rosler, & Roder, 2007) and from animal studies suggest that the development of auditory neural pathways and those that permit multi-sensory activity (e.g. audiovisual interactions) depend on early postnatal sensory input (Dmitrieva & Gottlieb, 1994; Gottlieb, 1997). Thus, differences in auditory processing could result from late prenatal or postnatal experiential input. Reports of early cochlear differences have been linked by one research group to brain masculinization and homosexuality in females (McFadden, 1993).

The scattered nature of the literature on sex-related differences in sensory development makes it impossible to draw firm conclusions. Health issues that arise from sex-related differences in sensory systems (such as supposed differences in pain receptors and the accepted need for different approaches to pain management in men and women) currently rest on a profoundly inadequate foundation of knowledge concerning the early development of sensory systems and the possible emergence of difference in response to differential “training” through sex-related differences in sensory experience and feedback in early development.

What physiological and anatomical differences need to be explained?

Biology has had its own “systems” revolution (Arnold, van Nas, & Lusic, 2009). In the future, knowledge of different levels of hormone production might extend to the examination of networks of gene activation, or the intersection of effects across varied levels of biological organization. Thus, the material reviewed in this section is ontologically “old-fashioned” and integrating knowledge about biology into accounts of behavioral sex differentiation will be the systems challenge for the future.

Hormone production

Prenatal differences in hormones related to sexual development lie at the heart of most biologically-based explanations of sex differences in health and disease. Yet only very recently have they been subject to deep scrutiny (Jordan-Young, 2010). During normal development of XX and XY fetuses, prenatal hormone levels differ. Finegan, Bartleman and Wong measured testosterone and follicle stimulating hormone (FSH) levels in amniotic fluid obtained from 14 to 20 weeks of gestation (Finegan, Bartleman, & Wong, 1989). Fluid from amnions containing male fetuses averaged twice the testosterone levels of fluid from amnions-carrying female fetuses.¹ Amnions containing female fetuses had follicle stimulating hormone concentrations seven times higher than fluid from male-bearing amnions. Knickmeyer et al. found similarly large differences in testosterone levels in amniotic fluid from male-bearing versus female-bearing amnions (Cohen’s $d = 2.0$), but no significant differences in estrogen levels in samples obtained between 16 and 21 weeks gestational age. Despite a large Cohen’s d , there is overlap (almost 20%) between male and female populations (Knickmeyer et al., 2005). During the first two to three months after birth, male infants experience a testosterone surge of unknown function, followed by a gradual decrease to a level, at seven months,

that remains stable until just before puberty (Forest, Cathiard, & Bertrand, 1973; Stukenborg, Colón, & Söder, 2010).

Despite this basic knowledge, much detail is missing. A list of unanswered questions includes: what are the dynamic interrelationships between the varied hormones produced by the fetus and the mother *in utero* and in the infant during the first months after birth? Are there feedback controls that modulate gonadal, adrenal and placental production? Which tissues have specific hormone receptors and what kind of turnover dynamics do they exhibit? Does hormone exposure work primarily by increasing body and brain size (and why might brain size matter)? Do hormones affect motor and sensory development (nerves, muscles and receptors)? Do they lay down different neural scaffolding in the brain? Because so little biological detail exists about how hormones produce behavioral outcomes, the “hormone” side of the phrase “hormones and behavior” operates as a kind of black box and can be used to explain all manner of sex-related patterns of health and disease later in life (Jordan-Young, 2010), sex-related differences in diseases such as autism and related neurological disorders (Simon Baron-Cohen & Hammer, 1997).

Weight and strength differences at birth

At birth boys outweigh girls by almost half a pound (effect sizes of .15–.40 i.e. 73–89% overlap in male and female birth populations) (Australian Inst. of Health and Welfare, 2000, p. 76; Crawford, Doyle, & Meadows, 1987; Davis et al., 1993) and CDC Growth charts (Center for Disease Control, 2000), although the weight differences disappear by ages 2–3 years. On average boys have a stronger grasp reflex at birth. At three months, there is evidence of greater leg strength, and at 9 months greater arm strength. However, the developmental trajectory of strength differences in infancy and toddlerhood is poorly documented. The differences in birth weight present a kind of paradox, given that there is a higher mortality rate for boys in the pre- and perinatal periods even though birth weight is considered one measure of good health. For a full analysis of the weight and strength studies see Table 3, Supplementary data.

Differences in brain anatomy

In a study of 51 male and 51 female fetuses aged 20–22 weeks, Hering-Hanit, Lipitz and Achiron found that the left hemispheres of both male and female fetuses were significantly larger than the right but observed no sex-related differences in hemisphere size (Hering-Hanit, Achiron, Lipitz, & Achiron, 2001). Biparietal measurements (differences range from 1.3 to 4.4%) or measurements of head circumference (differences range from 1.9 to 3.9%) on fetuses as young as 18 weeks through to newborns show that males have slightly larger brain or head sizes than females (Davis et al., 1993). For a full analysis of the brain anatomy studies see Table 4, Supplementary data.

In an as yet independently unconfirmed ultrasound study, Achiron, Lipitz and Achiron compared the length, width and thickness of the corpus callosum of male and female fetuses. Although they detected the corpus callosum in female embryos ($n = 14$) about a week earlier than in male embryos ($n = 5$) (16–17 weeks of gestation), thereafter they found no differences in the linear growth rate of the longitudinal and the transverse axes of the middle section of the corpus callosum.² Although this study suggests that CC thickness is greater in female than in male fetuses

¹ Papers that measure hormone levels in amniotic fluid refer to fetal hormone levels even though this is not what is measured. Even, as in this example, when the authors later discuss the fact that actual fetal levels have not been measured, they use the simplified locution, thus always leaving the impression that a particular measurement is far more specific than, in fact, it is.

² For the intricacies, pitfalls and limitations of corpus callosum measurement (see: Fausto-Sterling, 2000).

in the periods from 20 to 34 weeks, we do not know whether the difference persists postnatally (Achiron & Achiron, 2001; Achiron, Lipitz, & Achiron, 2001).

Since the postnatal increase in brain size and especially in synaptic connectivity far exceeds the small sex differences in size at birth (Stiles, 2008), a dynamic account of brain differentiation should include studies that relate postnatal experience to synaptic growth and connectivity (Chiel & Beer, 1997; Edelman, 1987). Early experiential differences combined with small initial size differences could explain the observations of Giedd et al. on emerging sex differences in several brain regions in children from ages 4 through adolescence (Giedd, Castellanos, Rajapakse, Vaituzis, & Rapoport, 1997; Nitin Gogtay et al., 2004, 2006; Lenroot & Giedd, 2008; Lenroot et al., 2007). Without understanding the developmental dynamics of brain differences it is impossible to evaluate widely cited theories of the origins of neurological disorders in boys and girls (D. H. Geschwind, Miller, DeCarli, & Carmelli, 2002; N. Geschwind & Galaburda, 1985). Baron-Cohen, for example, has promoted the idea that autism is an example of an “extreme male brain”. But he builds his argument on precisely the data on hormonal brain effects that we have found so lacking. Whatever the neurological components of diseases such as autism turn out to be, we believe they are best understood in developmental context, a point argued more fully in Part 2 of this essay.

Biological difference and behavior: association studies in 0–3 year olds

Prenatal hormones and activity levels

Although no direct evidence links prenatal hormones (of any type) to the types of sex-related differences in infant motor activity reported by Campbell and Eaton (1999), scattered reports suggest a general relationship between stress-related hormone levels and infant motor activity (D. W. Campbell & Eaton, 1999). For example, in a cohort of normal births, Rothenberg et al. (1996) reported a correlation between lower β -endorphin levels in the umbilical cord and decreased sensorimotor development between two days and three years of life (Rothenberg et al., 1996). Other studies suggest that early differences in activity level could, hypothetically, be related to sex-related differences in stress hormones, an effect that declines after birth (Buitelaar, Huizink, Mulder, de Medina, & Visser, 2003; Huizink, Robles de Medina, Mulder, Visser, & Buitelaar, 2003; de Weerth, van Hees, & Buitelaar, 2003). Subsequent increases in activity level differences in boys and girls might then have a new and different set of causes.

These findings are pertinent to general mechanisms affecting early motor activity, and raise currently unexamined questions: Are there subtle sex-related differences in stress-related hormones during the perinatal period? If so, given that low birth weight can affect stress hormone levels, might there also be more subtle cortisol effects with small differences in average birth weights? Progesterone-related compounds produced in the first part of the steroid biosynthetic pathways can, depending on which enzymes are present, continue either in the direction of glucocorticoid (cortisol related steroids) or androgen or estrogen related compounds. This raises the possibility that feedback emanating from the cortisol pathway could influence the production of sex-related steroids, which in turn might affect behavioral development.

Prenatal hormones and toy interest

In a recent review, Berenbaum et al. cite studies that correlate high prenatal androgen exposure in girls with increased probabilities of masculine toy choice in children older than age 3 (Berenbaum

& Bryk, 2008; Berenbaum, Martin, Hanish, Briggs, & Fabes, 2008). We differ with these authors on how best to interpret the body of work they cite. Specifically, (and at the risk of sounding Clintonesque!), we focus on what is meant by the word “how”. These authors cite animal studies to show “how sex hormones...induce sex differentiated...behaviors” (p. 281). However, animal studies as well as studies on humans with variations of sexual differentiation, show correlations between hormones and behavior, not specific biological or biosocial mechanisms. The mechanisms we seek to understand would tell us *how* behaviors emerge. Unearthing mechanism at the level we argue for entails a dynamic developmental approach which analyzes biosocial mechanisms in fine, progressive detail over frequent time intervals (Hui-Chin Hsu & Fogel, 2001, 2003a,b; Manuela Lavelli & Fogel, 2002, 2005).

In contrast to one recent study that correlated testosterone levels measured in amniotic fluid of 212 pregnant women with male-typical scores on a standardized parental questionnaire administered when the children were eight years old (Auyeung et al., 2009), a different research group directly observed sex-related play behavior in 13-month-old infants, after having measured amniotic and maternal serum levels of testosterone, estradiol and progesterone during the second trimester of pregnancy (van de Beek, van Goozen, Buitelaar, & Cohen-Kettenis, 2009). van de Beek et al. found no significant relationship between within-sex variation in prenatal testosterone and estradiol levels and preference for male or female toys. Unexpectedly, these authors found a positive relationship for boys between amniotic progesterone levels and masculine toy preference.

Prenatal hormones and vocalization; prenatal hormones and sensory development

We were unable to find research literature linking prenatal hormones to sex-related differences in vocalization; nor could we find any research literature linking prenatal hormones to sex-related differences in sensory responses such as smell, taste, orality, touch, hearing or vision in humans during the first three years of life.

Summary of correlation studies linking biology and behavioral development

Although some studies suggest a relationship between prenatal hormone exposure and play behaviors that appear several years after birth they do not offer a biologically satisfactory mechanistic understanding of this relationship. Nor could they, given that so many years (3–8) have elapsed and so many other experiences contributing to physiological, neurological and behavioral development have occurred. In order to provide background for the design of future studies which examine how prenatal hormone physiology interacts with the developmental experiences of infants and toddlers in the first three years after birth, we next examine current knowledge about postnatal experience. Again, we emphasize that developing a better approach to studying early developmental phenomena can aid us in understanding diverse health issues, including a range of neurologically-related problems such as autism, tic-disorders, dyslexia and attention deficit disorder.

What do we know about postnatal experience?

Adult perceptions

Reid reported that mothers rated their newborn sons as having broad, wide hands, noted that they looked tall, large and athletic, and appeared to be serious (Reid, 1994). In a similar study that also

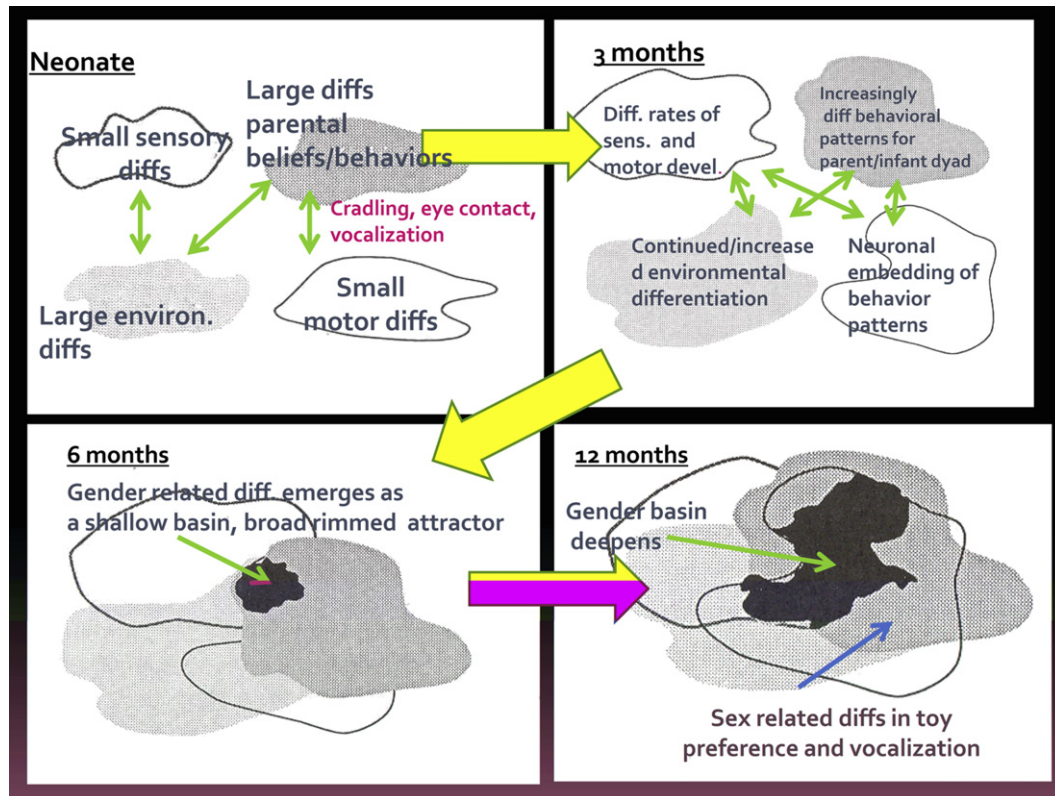


Fig. 2. Development of gender as an attraction basin as the result of four initial interacting systems.

included fathers, Rubin, Provenzano and Luria interviewed 30 pairs of parents (15 with sons and 15 with daughters) within the first 24 h after birth (Rubin, Provenzano, & Luria, 1974). The newborn infants did not differ by sex for length, weight or Apgar scores, but parents described daughters as little, beautiful, pretty and cute, significantly more often than they did their sons. Fathers made more strongly sex-stereotyped judgments (see also Sweeney & Bradbard (1988)). Whether such sex-stereotyping results in differences in actual behavior is unclear (Karraker, Vogel, & Lake, 1995; Will, Self, & Datan, 1976). Still, when mothers estimated the motor abilities of their infants, they believed the boys would excel at crawling down a slope, although in fact there were no infant differences in success on steep slopes (Mondschein, Adolf, & Tamis-LeMonda, 2000). In general, the social science literature linking adult perceptions of gender to specific developmental outcomes is weak, and further work is needed to build a theory in which the biological effects of socialization on the developing body can be better understood and theorized.

Parental vocalization

On average, parents spend more time vocalizing to daughters than to sons and the differences in parent's speech were greater in more naturalistic settings. Effect sizes range from moderate to very large (Leaper et al., 1998). The increased rate of vocalizations is found as early as the neonatal period. Only during teaching situations do researchers report that parents vocalize more to sons than daughters (Golinkoff & Ames, 1979). For a full analysis of the parental vocalization studies see Table 5, Supplementary data.

Parental play

Researchers, studying children aged 12–27 months, well after the emergence of sex-related toy preference in infants, found that

parents gave masculine toys to sons more often and feminine toys to daughters (Eisenberg, Wolchik, Hernandez, & Pasternack, 1985; Snow, Jacklin, & Maccoby, 1983) and reacted more positively to girls when they played with dolls or other female-identified toys and more negatively to boys when they played with dolls (Fagot, 1978).

Postnatal experience and behavior: association studies in 0–3 year olds

The evidence that parents behave differently depending on their child's sex is strongest in vocalization, and weak or non-existent in relation to infant activity and early toy preference. Self evidently, to obtain telling information about the role of experience in the emergence of sex-related differences in infants and toddlers, observers must study both the nurturer and the child as they interact, making observations that begin before the emergence of the behavior in question and continue until the behavior of interest is reliably manifested (Sung et al., 2010). A few investigations framed in this fashion have produced provocative data about experience and sex-related related behavioral differences.

In a longitudinal study of 16 infants, Lavelli and Fogel found a decrease in maternal attempts to get the infant's attention and an increase in face to face communication during the first three months after birth. They observed that holding the infant seemed to delay the development of face to face communication. Furthermore, compared to female infants, males exhibited "scant communication" (p. 297) and engaged actively for shorter time periods while held in their mothers' arms. The authors suggest that male infants are more irritable and emotionally labile than females and as a result, they adapt less well to being held (Manuela Lavelli & Fogel, 2002) (see also: Leeb & Rejskind (2004)).

During the first six months, mothers and infants spend their time in three repeating communication patterns—symmetrical,

asymmetrical and unilateral (Hui-Chin Hsu & Fogel, 2003a). These patterns can be conceptualized as “attractors” i.e. relatively stable but dynamic states (Thelen & Smith, 1994). Hsu and Fogel found that the unilateral attractor is the most stable, a stability relationship influenced by maternal parity, infant sex and infant age. Of particular interest is the greater stability of the unilateral pattern in mother–son dyads. Such early dyadic patterns may have later developmental consequences. For example, in one study of infant–mother–object triadic interactions in 6-month olds, longer episodes of infant initiated unilateral communication predicted better vocabulary comprehension at 12 months (Silvén, 2001). A single recent study in neonates suggests that cortical function is more developed in girls at birth (Thordstein, Lofgren, Flisberg, Lindcrantz, & Kjellmer, 2006). Thus, it seems possible that minor differences in size and nervous system development in neonates might affect the stability of dyadic attractor states in the first several months after birth, and could in turn affect later language development (see Fig. 2). This hypothesis gains some support from a longitudinal study of 62 mother–infant dyads examined at 6, 8, 17 and 24 months (Saxon, 1997).

Conclusion

On average, boys are slightly heavier and have slightly larger brains at birth. They have been exposed to higher levels of testosterone prenatally and experience a postnatal testosterone surge at three months, while girls have been exposed to higher levels of follicle stimulating hormone. Neonatal differences in motor activity level decline postnatally, but reemerge at 4 months. More complex behavioral differences, especially toy preferences and vocalization emerge toward the end of the first year of development and increase in size and stability over the following two years. At the same time, boys and girls are exposed to differing stimuli (toys, parental speech) which may affect neural development in a manner productive of observed difference. In Fig. 2 we illustrate how such small variations, which begin as individual differences might gradually create an attractor basin we call “gender” which then deepens and attracts a variety of behaviors to it.

These early differences may contribute to sex differences in developmental problems, especially related to neurological disorders and language, learning and activity disabilities. We have shown where we are lacking essential information and at the same time indicated the need for fine-tuned, longitudinal studies that emphasize the dynamics of emerging sex-related patterns. Methodologically, we insist that to study difference we must begin before it exists and observe its emergence. Theoretically, we argue that experience itself guides neural and thus behavioral development (Fausto-Sterling & García Coll, 2006). We spell out this latter argument in more specific detail in a subsequent paper (Fausto-Sterling et al., 2011).

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Appendix. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.socscimed.2011.05.051.

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