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Sexing the baby: Part 2 applying dynamic systems theory to the emergences of sex-related differences in infants and toddlers

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ABSTRACT

During the first three years of life, children acquire knowledge about their own gender and the gendered nature of their environment. At the same time, sex-related behavioral differences emerge. How are we to understand the processes by which bodily differentiation, behavioral differentiation and gendered knowledge intertwine to produce male and female, masculine and feminine? In this article, we describe four central developmental systems concepts applied by psychologists to the study of early human development and develop them in enough depth to show how they play out, and what sort of knowledge-gathering strategies they require. The general theoretical approach to understanding the emergence of bodily/behavioral difference has broad applicability for the health sciences and for the study of gender disparities. Using dynamic systems theory will deepen and extend the reach of theories of embodiment current in the health sciences literature.

Introduction

Understanding the development of gendered bodies is essential to an analysis of health disparities, disease prevention and treatment. Life history approaches to embodiment, including the body's relationship to sex, and gendered social milieu, require a starting point and a theory that can guide us as development proceeds; Previously, we assessed the state of knowledge about sex-related differences in the first three years of life (Fausto-Sterling, 2005; Fausto-Sterling, 2008; Fausto-Sterling, García Coll, & Schooler, 2008; Fausto-Sterling, García Coll, & Lamarre, 2011a). Here we dig more deeply into dynamic systems theory (DST) in order to demonstrate how it can apply to the study of embodied gender and to suggest new research paradigms that will guide us in the coming decades. Our proposals make more specific the calls of some social scientists to pay more attention to the development of sex-related differentiation in infancy and childhood as well as to broader social processes which shape human development (McIntyre & Edwards, 2009).

In an article memorializing Esther Thelen's work, Spencer, Clearfield, Corbetta, Ulrich, Buchanan et al., (2006) identify four critical dynamic systems concepts (Spencer et al., 2006). How might each of these apply to the study of early sex-related differences in behavior and what is their relevance for the study of gender and health? Our goal is to show that when we look at what we already know in the light of dynamic systems we can guide development of the next group of novel (i.e. rarely applied to the study of sex differences) observational and experimental studies. We focus on observations of sex-related differences from the prenatal period to three years. These early differences are not merely fixed biological starting points. Rather, they emerge and transform as the result of a dynamic interplay between body and experience.

A brief word about language. We try, whenever possible, to refer to group differences found in very young children as "sex-related". These differences overlap greatly between boys and girls, are variable within each group, and are not clearly a primary or secondary sex characteristic. Statistically, they correlate with natal genital sex and some believe that their early appearance means that they have a clear biological origin. On the other hand, we argue that the distinction between "biological" and "cultural" is not so clear. We use the word gender to indicate strongly held but culturally specific beliefs and practices about male and female, masculine and feminine. Both sex-related characteristics *and* gender can become embodied, although neither need be thought of as inborn or innate.

Concept #1- a new emphasis on timing

DST emphasizes that behavior, engaged in over time, influences nervous system structure and sets the stage for change. In Figs. 1

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and 2 we create a time line of sex-related events during the first 3 years. The data for these figures come from studies concentrated in Europe and North America. Thus, the schemata are not intended as representations of universal developmental patterns. To the contrary, we expect that similar studies conducted in other cultures will reveal variability of great interest to the topic of sex-related differentiation. For example, Fouts documents among foragers in Africa a wide variation in the percentage of hours each day that fathers spend holding their children. She further documents the manner in which social happenstance (matrilocality vs patrilocality, and availability of post-menopausal female relatives) affects parenting behaviors (Fouts, 2008). In a rare study of cross-cultural parenting differences within the United States Rooparine et al, makes two important findings. First among African American parents of 3–4 month old infants, increasing socioeconomic levels correlate with greater levels of maternal care. Second, in upper socioeconomic families fathers of daughters were more available than fathers of sons (Roopnarine, 1986) (Roopnarine, Fouts, Lamb, & Lewis-Elligan, 2005).

With the above caveats in mind, we turn to a more detailed look at Fig. 1, which diagrams much of the currently-existing knowledge about sex-related differences from birth to 6 months. During this

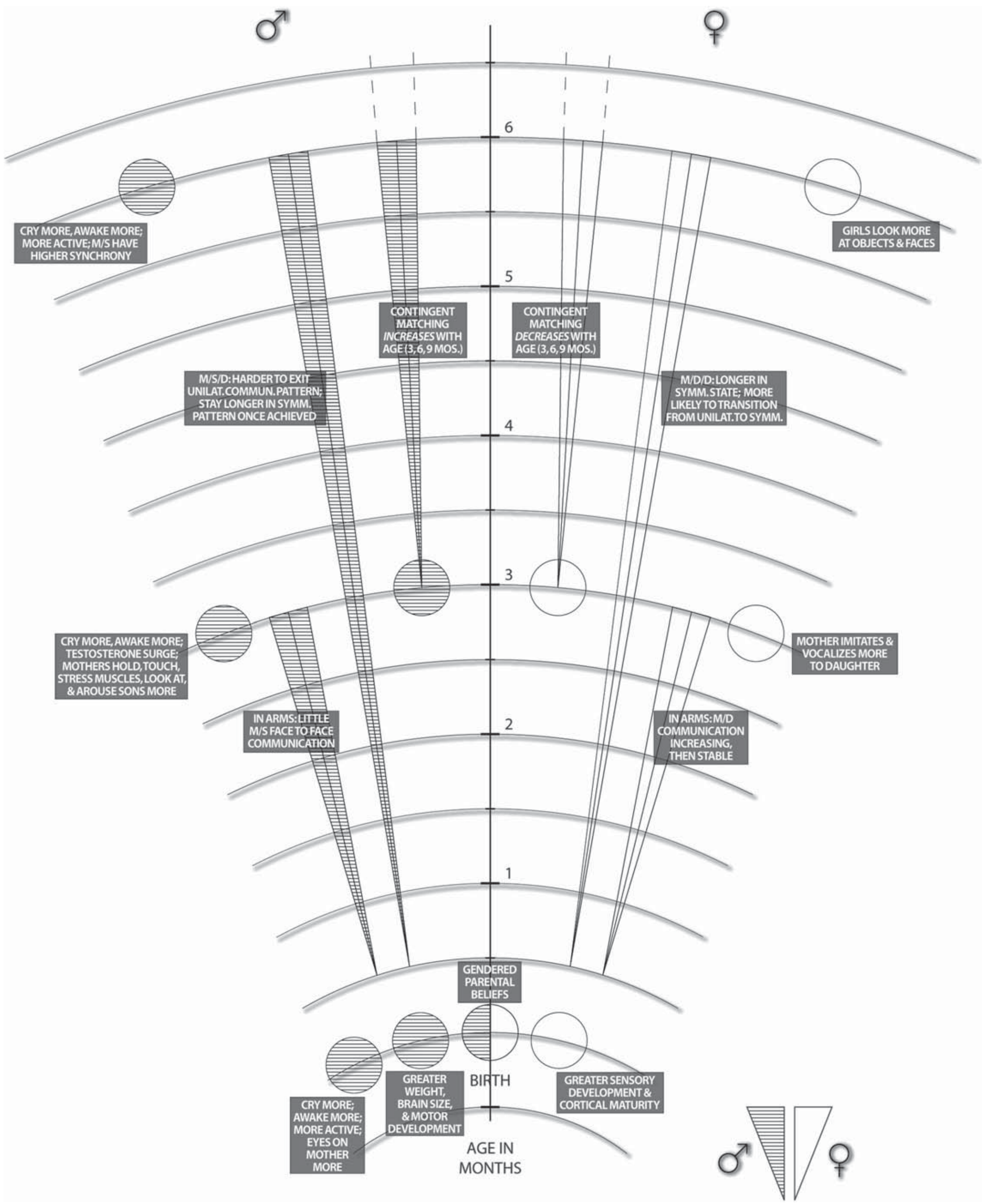

Fig. 1. Known differences in male and female development during the first six months following birth. Circles represent studies with a single time point. Triangles represent longitudinal studies with multiple, closely spaced time points. Dashes represent presumed continuation of behaviors. Abbreviations: M/S, mother/son; M/S/D, mother/son dyad; M/D, mother/daughter; M/D/D, mother/daughter dyad; Symm., symmetrical; Unilat., unilateral.

period existing studies focus on behaviors related to the function of the mother-infant dyad. The few continuous (weekly) studies are represented as long triangles. Cross-sectional studies are represented as circles. In addition to differences in weight, brain size and motor and sensory development (Fausto-Sterling, García Coll, & Lamarre, 2011a), neonatal starting points may include greater average brain cortical maturity in girls (Thordstein, Lofgren, Flisberg, Lindecrantz, & Kjellmer, 2006) and average differences in crying and fussing at birth, three months and six months (Moss, 1967; Phillips, King, & DuBois, 1978; Sadeh, Dark, & Vohr, 1996).

A study of the mother-infant dyad with weekly time points from birth to three months reveals sex-related variability in dyadic communication (Lavelli & Fogel, 2002). New studies of these early starting points will permit examination of the relationship between individual variability and the emergence of small group differences (see also Concept # 4 below). If, for example, the critical factors that shape early dyadic communication include levels of neural development, sleep and fuss patterns and physical size, we could correlate each of these variables with the development of dyadic communication patterns. If these, in turn, correlated with the sex of

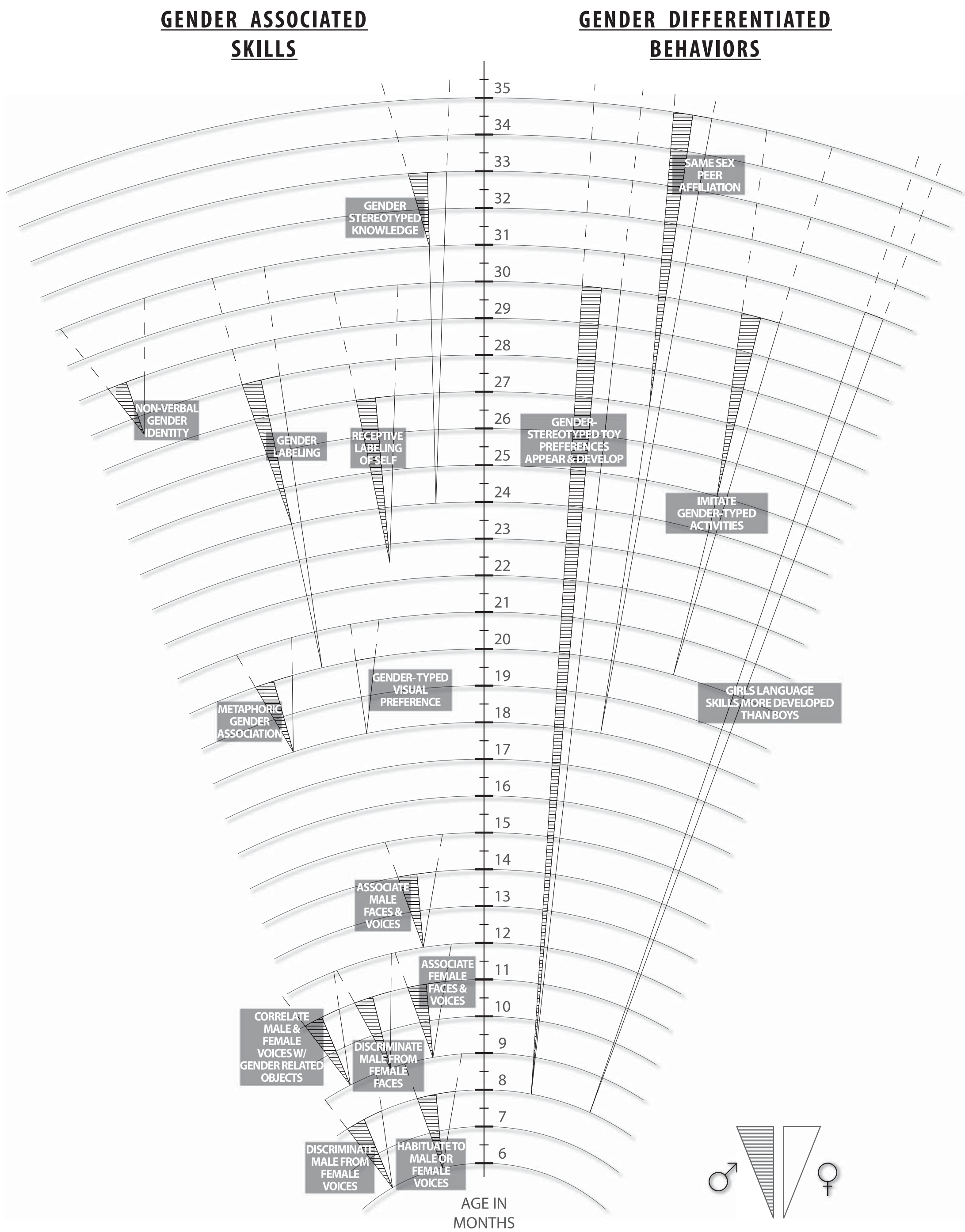

Fig. 2. A time line comparing the acquisition of gender-related skills with the appearance of gender differentiated behaviors from six to 35 months after birth.

the infant, then a process by which the development of early sex differences is initiated might be identified.

Fig. 1 also represents sex-related communication patterns found during the first 6 months. As defined by Hsu and Fogel (2003a), in a *symmetrical* pattern both mother and infant are mutually engaged; in an *asymmetrical* pattern, one partner actively tries to engage a passively attentive pair member and in *unilateral* communication, one partner tries a variety of means to engage the attention of a socially disengaged pair member. The mother-infant dyad cycles in and out of these various states; the more success the dyad has in achieving symmetrical communication at any one time, the greater success they will have in the following period. In other words, history and timing matter (Hsu & Fogel, 2003a). On average boys have a harder time self regulating and take longer to move from a unilateral to a mutually engaged state. Thus this state is still increasing in mother-son dyads at 3–9 months but has already stabilized in mother-daughter dyads. (Malatesta, Culver, Tesman, & Shepard, 1989; Tronick & Cohn, 1989; Weinberg, Tronick, Cohn, & Olson 1999)

In sum: (1) at birth enormous individual variability in developmental parameters exists; some of this variability rises to the level of average group differences between male and female infants; (2) from birth on, average sex-related differences in dyadic communication appear; these may develop into different patterns of vocal, physical and emotional interactions, measureable even at three months. Between 3 and 6 months other dyadic patterns emerge, some of which appear to be sex-differentiated. (3) from the beginning (possibly even before birth) we observe the expression of different behaviors brought to bear by both parent and infant; it is the dyadic interaction which shapes individual nervous systems in such a way that groups with overlapping but statistically differentiable behaviors start to emerge. Effects on neural development can be via the central and/or the peripheral nervous systems.

Differences in neural development could contribute to the different frequencies in boys and girls of developmental problems ranging from ADD and dyslexia to the family of autism-like disorders (Eliot, 2009). Feldman presents findings that the social, emotional and regulatory skills of children of depressed mothers are poorly developed, as are the underlying physiological systems that support social engagement (e.g. cortisol and serotonin levels and cardiac vagal tone). Feldman (2007a, b) has correlated the interrelated sequences (system) of mother-infant gaze synchrony in relationship to infant vocalization and affect development (Feldman, 2007a, b). She links the dynamic study of parent-infant synchrony to the analysis and treatment of infants referred to mental health clinics for feeding disorders and withdrawal. We argue that adding sex of infant as a variable to this dynamic development of physiology and emotion would profitably inform the study of sex-differentiated mental diseases as well as later-in life sex-differentiated patterns of mental health and illness (Fausto-Sterling, 2011).

By 6 months, infants can be studied as partially autonomous individuals. At this age they make transitions from primarily interacting in a maternally guided object frame to mixed frames and independent play with objects (Fogel, Garvey, Hsu, & West-Stroming, 2006). These emergent patterns can be seen in the very different kinds of studies on sex-related behaviors published after six months of age. In Fig. 2 we diagram critical events from ages 6 months to 3 years as two parallel time lines. The first documents the appearance of gender-related skills: the ability to differentiate male from female, the acquisition of knowledge about expected sex-related behaviors (gender stereotyped knowledge), and the ability to label self and others by sex. Later, beyond the ages covered in this review, children further develop a sense of gender permanency and ultimately they come to link external genitalia with the male or female sex (Fagot & Leinbach, 1989, 1993).

Boys and girls, both learn to identify males and females by face (even before 6 months!) and voice and to connect the right voices to the right faces (Martin, Ruble, & Szkrybalo, 2002; Poulin-Dubois, Serbin, & Berbyshire, 1998; Poulin-Dubois, Serbin, Kenyon, & Derbyshire 1994; Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). From 18 months to three years more sophisticated knowledge emerges, with the average timing differing by sex. At 18–24 months girls (but not yet boys) have gender stereotyped knowledge, gender-typed visual preference and recognize labels (Campbell, Shirley & Caygill, 2002; Fagot & Leinbach, 1989; Levy, 1999; Poulin-Dubois, Serbin, Eichstedt, Sen, & Beissel, 2002). By 20 months they can actively label according to gender, a skill boys exhibit in subsequent months. By 22 months girls can imitate gender-typed activities, again a skill which boys develop a few months later [references cited in (Martin, Ruble, & Szkrybalo, 2002)]. Again we note that it would be extremely instructive to study such developmental time lines in radically different cultural settings.

Using Fig. 2 we can correlate the acquisition of gender-associated skills with the appearance of sex-differentiated behaviors. For both sexes, language and toy preference differentiation start after infants can at least passively distinguish adult men from adult women, but well before any demonstrated specific knowledge about gender stereotypes or the ability to self label as male or female. From 18 months on children rapidly assimilate information concerning gender and by two years they actively perform it (Poulin-Dubois et al., 2002), with girls,on average, becoming "gender competent" a bit sooner than boys. Gender labeling and same-sex peer affiliation emerges for both boys and girls between two and three years of age, which means that by the time strong playmate preferences emerge children already have acquired significant and varied types of gender competence, including knowledge of their own gender (La Freniere, Strayer, & Gauthier, 1984).

In summary, the information represented on a time line in Figs. 1 and 2 provide a visual framework for understanding the dynamics of gender emergence. Transition points appear as development proceeds first within the context of the infant-care-giver dyad, then to the inclusion of objects, independent exploration and eventually peer interactions. At the same time we note the gradual acquisition of gender-related skills. Our time line raises critical questions: does initial variability in characteristics such as size, fussiness or activity lead to sex-related differences in dyadic formation? Do these in turn produce embodied differences in behaviors such as vocalization? Or different types of object preference or play behaviors? How might very different patterns of parenting restructure the framework established for Euro-American cultures [see (Feldman, 2007a, b), for example]?

Concept # 2-behaviors and other physiological states are softly-assembled

A softly-assembled behavior is temporarily stable and provides a platform for individual experimentation and future development. A behavior, or a state of health or disease, is an emergent property resulting from the interactions of several subsystems and the transition from one softly-assembled state to another involves a non-linear phase shift followed by a new period of stability. A closer examination of the reported difference in activity levels during the first year of development provides a useful example. Campbell and Eaton's (Campbell & Eaton, 1999) metanalysis of sex-related differences in infant activity levels demonstrates that there are small group differences in motor activity and thus likely in the rate of nervous system development in boys and girls during the first year. We are intrigued that the difference seems to disappear at three to four months, reappears at five months and increases in size thereafter to a moderate level in toddlers, an indicator that motor activity is a softly-assembled state (Eaton & Enns, 1986; Fausto-Sterling, García Coll, & Lamarre, 2011a).

Parental behavior patterns contribute to the soft assembly of motor activity. At 3 weeks mothers hold female infants at a greater distant, but attend to and hold male infants more often (Moss, 1967). They also stress male infant musculature more, stimulate and arouse males more and look more at their male infants. These differences in maternal behavior may have, in turn, resulted from the fact that males slept less and cried more. Lewis (Lewis, 1972) reported that mothers more frequently responded to the movement of three month old girls by vocalizing or looking, while the same movement in boys elicited holding and touching. Fathers have different dyadic patterns when playing with infants, and thus the distribution of maternal and paternal care as well as the same-sex or opposite-sex nature of the adult-infant dyad may contribute to differential care giving and emerging sex-related infant differences (Feldman, 2003; 2007a, b).

Neonatal activity levels may correlate with different rates of prenatal neural development—greater motor for boys, greater sensory for girls. Possibly, these neural-developmental differences even out by 4 months, leading to a decline in sex-related difference in activity levels (Fausto-Sterling, García Coll, & Lamarre, 2011a). Subsequent divergence might emerge from dyadic differences in parent-infant motor stimulation, affective development and language interaction. In this example, sex-related activity differences at birth can be understood as an attractor state underlain by some constellation of physiological system states. As these systems develop during the first four months, the strength of the motor activity attractor diminishes, but in months 5–12 a new and partially sex-differentiated activity attractor emerges. These new attractors would bear the history of the older, primarily physiologically based underpinnings, but differ from these because they have new social systems (parent-infant dyadic interactions) contributing to their soft assembly.

In this view, activity level is not a constant "thing" but rather a semi-stable state; the difference observed in the first few months may have a different underlying genesis than the difference measured after six months. This view contrasts theoretically with that of Campbell and Eaton (1999), who write: "The early appearance…suggests the difference is biological…gender-related environmental influences probably build on sex-based constitutional differences…" (p.13). We suggest an ongoing flow or process that is *at once* biological and experiential. Differing frequencies of both language and motor disorders that appear in school age boys and girls, could well have begun their developmental trajectory in these softly-assembled states observed during infant development.

Concept 3: embodiment

The body integrates perception, action and cognition. Esther Thelen and her colleagues and students have demonstrated with great elegance that experience shapes embodiment (Corbetta & Thelen, 2002; Newell, Liu, & Mayer-Kress, 2003; Thelen, 1995; Thelen & Corbetta, 2002, pp. 59–79; Thelen, Fisher, & Ridley-Johnson, 2002; Thelen, Schoener, Scheier, & Smith, 2001; Thelen & Smith, 1994). Experimenting with 2.5–3 month old infants whose legs were loosely tethered to an overhead mobile, Thelen took advantage of initially random and spontaneous leg movements. She postulated the formation of neural maps connecting vision and proprioception to produce a presumably pleasurable outcome–seeing the mobile move. Higher order cognition develops through "reiterative mapping and remapping that is the emergent result of coherent experience…The radical idea here is that the sophisticated skills shown by infants in the mobile task are created by the performance and not just reflected in the performance." (p. 17) (Thelen, 2000). We suggest that this same radical idea can be applied to the emerging performance of gender.

Each newborn faces an immense developmental task. The adult brain has 10^{11} neurons connected by 10^{15} synapses. How do these connections become established during development in such a way that each of us makes sense of the world and on the whole functions successfully within it (Chklovskii, Mel, & Svoboda, 2004; Fields, 2008)? The brain begins development in the early embryo and the differentiation of the cortex into functional areas happens gradually *in utero* in response to intra and intercellular developmental cues (Sur & Rubenstein, 2005). These cues operate as part of a molecular control system which directs development forward until the network logic becomes self-reproducing (a stable differentiated state) (Davidson et al., 2002). Such molecular processes produce an anatomical framework, a scaffold of connections linking neurons and brain areas.

Sensory information barrages fetuses in the womb and babies after birth and the nervous system responds accordingly (Kisilevsky et al., 2003). During the first six months after birth, for example, the total length of dendrites in cells in the prefrontal cortex increases more than 200-fold (Quartz, 2003). Quartz writes that "neural development during the acquisition of major cognitive skills is best characterized as a progressive construction of neural structures, in which environmentally derived activity plays a role …" (p. 292) Understanding the neural basis of cognitive development requires the analysis of multiple organizational levels, from the cellular to the whole organism (Elman et al., 1996; Mareschal, 2007).

Embodiment is a social process. Social interaction affects neural development via chemical signaling including hormones such as adrenalin and chemical messengers such as dopamine. Examples from the animal world abound: in rodents maternal licking and grooming programs their offspring's neuroendocrine stress responses when they reach adulthood (Francis, Diorio, Liu, & Meaney, 1999; Francis & Meaney, 1999), while separation from the mother induces biochemical changes in the neurotransmitter receptors within the brain's limbic system, which integrates emotional states with stored memories of physical sensations. Hearing the mother's vocalization, however, modulates these effects. In this and other examples, the social environment produces physical and physiological traces within the nervous system, that is, the social becomes literally embodied (Han & Northoff, 2008; Poeggel et al., 2003; Poeggel, Nowicki, & Braun, 2003; Ziabreva, Poeggel, Schnabel, & Braun, 2003; Ziabreva, Schnabel, Poeggel, & Braun, 2003).

In humans, the vasopressin and oxytocin neuropeptide systems, required for social bond formation and emotion regulation, change in response to early social experience (Fries, Ziegler, Kurian, Jacoris, & Pollak, 2005). Allan Schore proposes that infant emotional systems develop within the dynamic of face-to-face interactions with the primary caregiver (Schore, 1994). Facial information patterns trigger changes in processes such as infant heart rate and respiration and ultimately affect the growth and neural connectivity of specific brain regions, shaping embodied emotion (Schore, 2000; Feldman, 2007a, b; Feldman, 2007a, b). Parental training of infant physiology includes calming, establishment of sleep cycles eating, eliminative, and exploratory behaviors (Harkness et al., 2007; Wexler, 2006).

How might these principles of embodiment apply to sex-related behavioral differences, for example, in the emergence of toy preferences in infants and toddlers? Preference for choosing or playing with specific types of toys appears at about 9–12 months and represents a stable sex-related attractor system in subsequent months (Fausto-Sterling, García Coll, & Lamarre, 2011a). In one study, for example, 12–15 month old boys played more frequently

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with transport toys than their female peers who played more often with soft toys and dolls (Smith & Daglish, 1977). Seventeen month old boys prefer trucks over dolls (but there are no differences for a variety of other toys (e.g. tea sets, brush sets, or blocks) (van de Beek, 2005; Zosuls et al., 2009).

What elements might contribute to differences in toy preference? Boys are, on average, heavier and somewhat more active at birth (Australian Inst. of Health and Welfare, 2000; Crawford, Doyle, & Meadows, 1987; Davis et al., 1993) and CDC Growth Charts (Center for Disease Control, 2000). Although the size differences are statistically small to moderate, parents perceive large differences in their newborns. They describe newborn daughters as fine, little, weak, quiet and delicate with far greater frequency than they do their sons (effect sizes .68–1.41) (Rubin, Provenzano, & Luria, 1974; Sweeney & Bradbard, 1988). Surprisingly, there are no studies that determine whether these parental perceptions translate into sex-related parent-child behaviors.

The brilliant studies of Rovee-Collier and colleagues demonstrate that infants as young as three months can recognize and categorize objects. Furthermore, their object memory and their ability to associate categories depend on continued or intermittent exposure (Bhatt, Wilk, Hill, & Rovee-Collier, 2004; Galluccio & Rovee-Collier, 2005)[See also: (Mareschal & Quinn, 2001)]. Studies of toy preference development need to detail the kinds and numbers of toys found in an infant's environment from birth, how (and how often) specific toys are offered by caregivers, and what unprompted interest the infant exhibits. Does visual-sensory training result from differential exposure and then translate into preference? We suggest here the importance of conceptualizing toy preference as an embodied, softly-assembled trait; we need to know more about what subsystems underlie the preference trait, how they interact to stabilize preference.

Fogel and colleagues analyzed changing mother-infant dyadic relationships in the context of toy objects from one month to 26 months of age (Fogel, Garvey, Hsu, & West-Stroming, 2006). They examined the transition from a primarily social frame (attractor state) in which mother and infant engage in face-to-face communication play relationships, through a guided object attractor (mother demonstrates, infant observes), and finally to a stable endpoint in which the infant explores the object while the mother observes. Fogel's group argues that individual competence at playing with a particular toy is a relational achievement, "the product of a historical process of mutual regulation within the dyad" (p.224). Furthermore, they suggest that infants' physical self-awareness and use of their own bodies emerge from dyadic relational interactions. Baby Richard's mother, for example, used words to describe a toy's properties, encouraged him to practice reaching, and only talked about topics related to the toy. Betsy's mother, however, emphasized words, sounds and singing by playing with the toy. She also used her own body in an exaggerated way, smiling, laughing and making facial expressions. Betsy, in turn, looked more at both the play objects and her mother, with an increase in vocalization and smiling.

If, as Fogel et al suggest, play objects carry relationally developed social significance, then it is plausible to hypothesize that toy *preference* in infants and young toddlers is an emotional outcome of the play history of the caregiver-infant system. Furthermore, as the above description suggests, vocalization skills may also owe at least a portion of their development to different dyadic play frames and behaviors. By using dynamic systems to structure the analysis of sex-related differences in toy preference, we open the door to new analytical approaches and a deepening of our developmental understanding. The principle of embodiment is applicable to the emergence of gendered differences in health and disease as well the normative differences discussed by clinical psychologists.

Concept 4: "a new respect for individuality" Spencer et al (2006)

Most sex differences present a conundrum. On the one hand, we make verifiable claims about statistically significant group differences. On the other, the differences are usually small enough that we are reluctant to apply policies or specify health care based on the group to any particular individual. Women and men may, on average, have different symptoms for heart attacks. But we would not want to ignore a "male typical" symptom because a woman is exhibiting it. Thelen's insistence on studying individual patterns of development is thus highly relevant to the study of sex-related differences, in which we see initial differentiation that barely rises to the level of group difference diverge by age three into a few larger reliable group differences. Emphasizing individual developmental variability enables us to reframe the basic question of difference: how do larger group differences emerge with time from a starting point of large individual variability but small group differences?

As an example, let's consider vocalization in the context of neural development. Three critical processes–myelination, synapse formation in response to specific experiences, and the overproduction of synapses followed by synaptic pruning (also influenced by experiential input)–begin before birth but occur actively in the post-natal environment, and in some cases though adolescence (Couperus & Nelson, 2006, pp. 85–105). Relevant to the acquisition of speech and vocalization are the facts that synapse formation in the auditory cortex climbs steeply in the months before and after birth, peaks between 2 and 3 months, and gradually declines thereafter, reaching adult levels by about 10 years of age. Synapse formation in the brain area associated with language and vocalization is low at birth, increases steadily in the post-natal period, peaks at about 8 months and declines slowly to adult levels by 15–18 years. Thus from the neuroanatomical evidence alone, we would expect that early experiences of hearing and vocalizing combined with the state of development of critical brain areas at birth would be crucial for language acquisition. Furthermore, individual genetic differences, prenatal growth, nutrition and maternal stress, possibly differences in prenatal sexual differentiation, birth trauma, etc. produce great individual variability in the relevant neural scaffolding present at birth.

From birth (or perhaps earlier) language perception shapes aspects of brain development. Neonates, for example, can discriminate between rhythmically different languages, two month olds orient more rapidly to their native language, and four month olds can distinguish between languages with similar rhythmic properties. Furthermore, auditory regions of the cerebral cortex develop specificity during the first year (Dehaene-Lambertz, Hertz-Pannier, & Dubois, 2006). Thus, different degrees and patterns of adult speech oriented toward individual infants likely affect the speed and complexity of language acquisition by inducing changes in the auditory and language cortex. One metanalysis of the speech of mothers and fathers to boys and girls showed larger effect sizes in speech, especially in naturalistic settings, directed toward infants and toddlers than toward older children (Gleason & Ely, 2002, pp. 127–154).

Scattered evidence (Fausto-Sterling, García Coll, & Lamarre, 2011a) raises the possibility that girls' visual and auditory systems are slightly more developed than boys' at birth. But suppose a greater development of visual and auditory systems at birth contributes to the speed of language development? The earliest reported sex-related differences in infant vocalization is 3–6 months, just following the peak of synaptic formation in the auditory cortex and well into the period of synaptic increase in the language and vocalization areas of the cortex. If we considered language development as an individual characteristic we could study the individual patterns that link sensory development, especially auditory and visual to vocalization. In early development this might be a fruitful way to approach the mechanisms of language development.

Mother-infant interactions are also critical for language development. Twelve week old infant girls attended more to auditory stimuli than did boys, for example, and mothers also spoke more to the infant girls and respond vocally more often to female infant vocalization than to male infant vocalization (Lewis, 1969; Lewis, 1972; Lewis, 1975; Lewis & Freedle, 1973; May, 1995). It is exactly during this early period of call and response that the auditory cortex, via *experience dependent* neuronal growth increases steeply. (By growth we mean synaptogenesis (neuron branching and connectivity) as well as continued birth of new neurons).It is thus a reasonable hypothesis that neural maturation of the auditory and vocalization systems is guided by adult-infant interactions (Gottlieb, 1997). Such guidance means that sensory development is neither autonomous nor a property of the individual infant. Rather, the *system* of call and response includes at least two people—infant and caregiver—one of whom depends on auditory input for the very development of the neurosensory systems that underlie hearing and permit the subsequent development of speech production.

Some literature suggests the importance for speech acquisition of infant attachment and emotional development (Locke, 2001; Saxon, 1997). Schore argues that the early visual and auditory attachment experiences between mother and infant affect growth-regulating brain biochemicals such as dopamine and noradrenaline, substances which in turn regulate brain. brain maturation. (Feldman & Eidelman, 2003; Schore, 2000, 2001a, b). Lewis similarly argues that “each episode of real-time cognitive–emotional activity leaves some degree of synaptic change in its wake” (p. 272) (Lewis, 2005). These points of view emphasize our claim that understanding the development of sex-related differences in verbal abilities will require micro-level descriptions of dyadic affect exchange and emotional development in correlation with the exercise of auditory and vocal exchanges. More generally, we believe that initial variability can be analyzed without regard to sex differences, but that sex-related experiences initiate a process of embodiment in which group differences become more visible. Although we have illustrated this idea with an account of the emergence of sex-related differences in vocalization, the theoretical approach is equally applicable to the development of sex-related differences in health and disease.

Conclusion

In this essay we name four concepts derived from dynamic systems approaches to the study of human development. The four principles are: a new emphasis on timing, the concept of soft assembly, the concept of embodiment and a new emphasis on individual variability. We have elaborated their relevance to the study of sex and gender in early childhood, but we believe that the general approach has far-reaching applications, especially to the study of disparities (be they ethnic, racial or gender-based) in health and disease. We have pointed to the existence of sex differences in affliction frequency in a number of neurologically related diseases as one possible location to apply the principles of dynamic systems to the study of disease emergence. It now appears that early signs of autism spectrum problems can be detected in infants in their first year of development. Is the sex difference in frequency also already evident? Is it as large as it later becomes? The focus on developmental systems and the emergence of phenomena over time would offer answers of some importance to the above questions.

The proposed methodology, however, has much greater application, especially for the analysis of chronic disease patterns in adulthood. As an example we consider so-called essential hypertension in African Americans compared to European Americans. The idea that our bodies seek homeostasis, a stability regulated by feedback control, has dominated our accounts of physiology. As with a thermostat controlling room temperature, if blood pressure were controlled by homeostasis, then any time it went above or below a set point, homeostatic feedback mechanisms ought to bring it into normal range [on genes and race see: (Fausto-Sterling, 2004)].

However, in normal adults experience predictable rises and falls in blood pressure over a 24 h period. Blood pressure does not seem to return to a single set point, but instead is regulated (Sterling, 2004, pp. 17) by employing *allostasis*—mechanisms that involve the brain and whole body and that change the controlled variable (be it temperature, blood pressure or insulin-controlled levels of blood sugar) by overriding local feedback controls to meet anticipated demand, (Schulkin, 2003; Sterling & Eyer, 1988, pp. 629). The allostasis model proposes that hypertension is a response to an experience-based need to remain vigilant to a variety of insults—be they racial hostility, enraging acts of discrimination, or living in the shadow of violence. The framework of allostasis, in which pathologically high blood pressure emerges as a step-wise, cumulative and predictable response to life stress, is a dynamic model which can be used to investigate the relationship between race and hypertension. It suggests developmental research, for example, starting with studies of the relationships between important childhood stressors and incremental hypertensive responses.

Enough work using dynamic systems has been done to explicate what a redirected research program, one that emphasizes developmental process over static, cross-sectional difference might entail. We identify five critical features of a dynamic systems research program:

- Conduct longitudinal studies (Grannot & Parziale, 2002; Fogel, Garvey, Hsu, & West-Stroming, 2006) with time points closely enough spaced to make visible the dynamics of development (Camras & Witherington, 2005; Granic, Hollenstein, Dishion, & Patterson, 2003; Granic & Lamey, 2002; Hollenstein, Granic, Stoolmiller, & Snyder, 2004; Granic, O'Hara, Pepler, & Lewis, 2007; Thelen, 1995; Thelen, Schoener, Scheier, & Smith, 2001; Thelen & Smith, 1998).
- Where possible conduct detailed direct observation in naturalistic setting.
- Use and develop statistical methods suitable to analyzing detailed data collected from small samples. At least three methods—state- space grids, growth curve analysis and cross platform studies—provide tools to produce a process-oriented account of sex-related behaviors. State-Space Grids offer a graphical analysis of moment-by-moment data, allowing one to identify and track stable (attractor) states. Details on methods and available free software can be found at http://www.statespacegrids.org/. (Granic & Hollenstein, 2003; Granic & Lamey, 2002; Hollenstein, Granic, Stoolmiller, & Snyder, 2004; Lewis, Lamey, & Douglas, 1999). A different approach to analyzing longitudinal data can be found in the variety of methods designed to analyze growth curves (Burchinal, Nelson, & Poe, 2006).
- Develop cross-disciplinary endeavors aimed at correlating real-time measures of neural and physiological function with directly observed behaviors (Sadato et al., 2008) (Swain, Lorberbaum, Kose, & Strathearn, 2007; Swain et al., 2008). A prototype that might, with careful thought, be applied to the study of sex-related differences is an examination of the effects of the Newborn Individualized Developmental Care and

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Assessment Program on preterm infants. This study combines measures of behavior, of neural development (MRI's and EEG) and physiological development to evaluate the effects of early experience, providing, a rich and embodied picture of the effects of experience on development. (Als et al., 2004; Dubois, Hertz-Pannier, Dehaene-Lambertz, Cointepas, & Le Bihan, 2006).

- Include a greater number of study designs aimed at investigating the adult-infant dyad (in infants) and subject-peer units in toddlers and young children or more generally, the social milieux in which individuals develop.

At birth, enormous individual variability in behaviors, brain sizes, motor activities and sensory acuities exist. But each physiologically distinct child is born into an adult-child unit operating within a culture that imposes a certain degree of uniformity with regard to sex-related rearing practices. We conceive of stable sex-related behaviors as *attractors* (stable patterns of relationships between and within the systems making up the behavior) (We got the idea of gender as an attractor from (Harris, 2005).) attractors are dynamically stable; in development old attractors fade and new ones emerge, as for example in the transition from crawling (attractor 1) to walking (attractor 2). Fogel, Garvey, Hsu, & West-Stroming, (2006) describe development as "the destabilization, re-organization and re-stabilization of the collective system of historical attractors" (p. 31) (Fogel, Garvey, Hsu, & West-Stroming, 2006). For example, we hypothesize that during the first six months (See Fig. 1) the stability of communication in arms and the symmetrical state itself are deeper (and thus more stable) attractors for mother-daughter than for mother-son dyads. Vocalization may be enabled by location within this attractor, and dyadic vocal interactions begin to develop into their own attractor state, a deeper or stronger attractor for mother-daughter than for mother-son dyads.

It is too soon to present a finished theory of the development of sex-related differences in infants and toddlers. But it is not too soon to turn our research efforts to more dynamic, intermodal studies. These efforts ought always to hold in mind the concept of embodiment, that experience changes the body and is not merely driven by events internal to the individual. The result of this new phase of study will be a less reductive and more dynamic understanding of bodies in their social and cultural contexts.

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References

Als, H., Duffy, F. H., McAnulty, G., Rivkin, M. J., Vajapeyam, S., Mulkern, R. V., et al. (2004). Early experience alters brain function and structure. *Pediatrics, 113*(4), 846–857.

Australian Inst. of Health and Welfare, N. P. S. U. (2000). *Australia's mothers and babies*. Canberra: Australian Institute of Helath and Welfare. 76.

Bhatt, R. S., Wilk, A., Hill, D., & Rovee-Collier, C. (2004). Correlated attributes and categorization in the first half-year of life. *Developmental Psychobiology, 44*(2), 103–115.

Burchinal, M. R., Nelson, L., & Poe, M. (2006). IV. Growth curve analysis: an introduction to various methods for analyzing longitudinal data. *Monographs of the Society for Research in Child Development, 71*(3), 65–87.

Campbell, A., Shirley, L., & Caygill, L. (2002). Sex-typed preferences in three domains: do two-year-olds need cognitive variables? *British Journal of Psychology, 93*(Pt 2), 203–217.

Campbell, D. W., & Eaton, W. O. (1999). Sex differences in the activity level of infants. *Infant and Child Development, 8*(1), 1–17.

Camras, L. A., & Witherington, D. C. (2005). Dynamical systems approaches to emotional development. *Developmental Review, 25*, 328–350.

Center for Disease Control. (2000). *2000 CDC growth charts: United States*. http://www.cdc.gov/growthcharts/ Retrieved January 14, 2008, from.

Chklovskii, D. B., Mel, B. W., & Svoboda, K. (2004). "Cortical rewiring and information storage. *Nature, 431*(7010), 782–788.

Corbetta, D., & Thelen, E. (2002). *Behavioral fluctuations and the development of manual asymmetries in infancy: contributions of the dynamic systems approach. Handbook of Neuropsychology*. S. J. Segalowitz and I. Rapin. Elsevier Science. 8-Part 1.

Couperus, J. W., & Nelson, C. A. (2006). *Early brain development and plasticity. Blackwell handbook of early childhood development*. K. McCartney and D. Phillips. Malden, MA: Blackwell.

Crawford, M., Doyle, W., & Meadows, N. (1987). Gender differences at birth and differences in fetal growth. *Human Reproduction, 2*(6), 517–520.

Davidson, E. H., Rast, J. P., Oliveri, P., Ransick, A., Calestani, C., Yuh, C.-H., et al. (2002). A genomic regulatory network for development. *Science, 295*(5560), 1669–1678.

Davis, R., Cutter, G., Goldenberg, R., Hoffman, H., Cliver, S., & Brumfield, C. (1993). Fetal biparietal diameter, head circumference, abdominal circumference and femur length. A comparison by race and sex. *Journal of Reproductive Medicine, 38*(3), 201–206.

Dehaene-Lambertz, G., Hertz-Pannier, L., & Dubois, J. (2006). Nature and nurture in language acquisition: anatomical and functional brain-imaging studies in infants. *Trends in Neurosciences, 29*(7), 367–373.

Dubois, J., Hertz-Pannier, L., Dehaene-Lambertz, G., Cointepas, Y., & Le Bihan, D. (2006). Assessment of the early organization and maturation of infants' cerebral white matter fiber bundles: a feasibility study using quantitative diffusion tensor imaging and tractography. *Neuroimage, 30*(4), 1121–1132.

Eaton, W. O., & Enns, L. R. (1986). Sex differences in human motor activity level. *Psychological Bulletin, 100*(1), 19–28.

Eliot, L. (2009). *Pink brain, blue brain*. Boston, Houghton, Mifflin, Harcourt.

Elman, J. L., Bates, E. A., Johnson, M. H., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking innateness: a connectionist perspective on development*. Cambridge: MIT Press.

Fagot, B. I., & Leinbach, M. D. (1989). The young child's gender schema: environmental input, internal organization. *Child Development, 60*, 663–672.

Fagot, B. I., & Leinbach, M. D. (1993). Gender-role development in young children: from discrimination to labeling. *Developmental Review, 13*, 205–224.

Fausto-Sterling, A. (2004). Refashioning race: DNA and the politics of health care. *Differences: A Journal of Feminist Cultural Studies, 15*(3), 1–37.

Fausto-Sterling, A. (2005). The bare bones of sex part I: sex and gender. *Signs, 30*(2), 1491–1527.

Fausto-Sterling, A. (2008). "The bare bones of race. *Social Studies of Sciences, 38*(5), 657–694.

Fausto-Sterling, A. (2011). Gender Variance in Children. *Journal of Homosexuality*, in press.

Fausto-Sterling, A., García Coll, C., & Lamarre, M. (2011a). Sexing the Baby: part 1 – what do we really know about sex differentiation in the first year of life? *Social Science & Medicine*, under revision.

Fausto-Sterling, A., García Coll, C., & Schooler, D. (2008). *Towards a dynamic study of gender in infant development*. Third Gender and Development Meetings. San Francisco, California.

Feldman, R. (2003). Infant-mother and infant-father synchrony: the coregulation of positive arousal. *Infant Mental Health Journal, 24*(1), 1–23.

Feldman, R. (2007a). On the origins of background emotions: from affect synchrony to symbolic expression. *Emotion, 7*(3), 601–611.

Feldman, R. (2007b). Parent-infant synchrony and the construction of shared timing; physiological precursors, developmental outcomes, and risk conditions. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 48*(3-4), 329–354.

Feldman, R., & Eidelman, A. I. (2003). Skin-to-skin contact (Kangaroo Care) accelerates autonomic and neurobehavioural maturation in preterm infants. *Developmental Medicine & Child Neurology, 45*(4), 274–281.

Fields, R. D. (2008). White matter in learning, cognition and psychiatric disorders. *Trends in Neurosciences, 31*(7), 361–370.

Fogel, A., Garvey, A., Hsu, H.-C., & West-Stroming, D. (2006). *Change Processes in relationships: a relational-historical research approach*. Cambridge: Cambridge University Press.

Fouts, H. N. (2008). Father Involvement with Young children Among AKA and Bofi Foragers. *Cross-Cultural Research, 42*(3), 290–312.

Francis, D., Diorio, J., Liu, D., & Meaney, M. J. (1999). Nongenomic transmission across generations of maternal behavior and stress responses in the rat. *Science, 286*(5442), 1155–1158.

Francis, D. D., & Meaney, M. J. (1999). Maternal care and the development of stress responses. *Current Opinion in Neurobiology, 9*(1), 128–134.
Fries, A. B., Ziegler, T. E., Kurian, J. R., Jacoris, S., & Pollak, S. D. (2005). "Early experience in humans is associated with changes in neuropeptides critical for regulating social behavior. *Proceedings of the National Academy of Sciences of the United States of America, 102*(47), 17237–17240.
Galluccio, L., & Rovee-Collier, C. (2005). Updating reactivated memories in infancy: II. Time passage and repetition effects. *Developmental Psychobiology, 47*(1), 18–30.
Gleason, J. B., & Ely, R. (2002). *Gender Differences in Language Development. Biology, society, and behavior: The development of sex differences in cognition*. A. McGillicuddy-De Lisi and R. De Lisi. Westport: Ablex.
Gottlieb, G. (1997). *Synthesizing nature-nurture: prenatal roots of instinctive behavior*. Mahwah: Lawrence Erlbaum.
Granic, I., & Hollenstein, T. (2003). Dynamic systems methods for models of developmental psychopathology. *Development and Psychopathology, 15*(3), 641–669.
Granic, I., Hollenstein, T., Dishion, T. J., & Patterson, G. R. (2003). Longitudinal analysis of flexibility and reorganization in early adolescence: a dynamic systems study of family interactions. *Developmental Psychology, 39*(3), 606–617.
Granic, I., & Lamey, A. V. (2002). Combining dynamic systems and multivariate analyses to compare the mother-child interactions of externalizing subtypes. *Journal of Abnormal Child Psychology, 30*(3), 265–283.
Granic, I., O'Hara, A., Pepler, D., & Lewis, M. D. (2007). A dynamic systems analysis of parent-child changes associated with successful "real-world" interventions for aggressive children. *Journal of Abnormal Child Psychology, 35*(5), 845–857.
Grannot, N., & Parziale, J. (2002). Microdevelopment: A process-oriented perspective for studying development and learning. In N. Grannot, & J. Parziale (Eds.), *Microdevelopment: Transition processes in development and learning* (pp. 1–28). Cambridge: Cambridge University Press.
Han, S., & Northoff, G. (2008). Culture-sensitive neural substrates of human cognition: a transcultural neuroimaging approach. *Nature Reviews Neuroscience, 9*(8), 646–654.
Harkness, S., Super, C. M., Moscardino, U., Rha, J.-H., Blom, M., Huitrón, B., et al. (2007). Cultural models and developmental agendas: Implications for arousal and self-regulation in early infancy. *Journal of Developmental Processes, 2*(1), 5–39.
Harris, A. (2005). *Gender as Soft Assembly*. Hillsdale: The Analytic Press.
Hollenstein, T., Granic, I., Stoolmiller, M., & Snyder, J. (2004). Rigidity in parent-child interactions and the development of externalizing and internalizing behavior in early childhood. *Journal of Abnormal Child Psychology, 32*(6), 595–607.
Hsu, H.-C., & Fogel, A. (2003a). Stability and transitions in mother-infant face-to-face communication during the first 6 months: a microhistorical approach. *Developmental Psychology, 39*(6), 1061–1082.
Kisilevsky, B. S., Hains, S. M., Lee, K., Xie, X., Huang, H., Ye, H. H., et al. (2003). Effects of experience on fetal voice recognition. *Psychological Science: A Journal of the American Psychological Society/APS, 14*(3), 220–224.
La Freniere, P., Strayer, F. F., & Gauthier, R. (1984). The Emergence of Same-Sex Affiliative Preferences among Preschool Peers: A Developmental/Ethological Perspective. *Child Development, 55*(5), 1958–1966.
Lavelli, M., & Fogel, A. (2002). Developmental changes in mother-infant face-to-face communication: birth to 3 months. *Developmental Psychology, 38*(2), 288–305.
Levy, G. D. (1999). "Gender-typed and non-gender-typed category awareness in toddlers. *Sex Roles, 41*(11-12), 851–873.
Lewis, M. (1969). "Infants' responses to facial stimuli during the first year of life. *Developmental Psychology*, .
Lewis, M. (1972). State as an infant-environment interaction: an analysis of mother-infant interaction as a function of sex. *Merrill Palmer Quarterly*, .
Lewis, M. (1975). Early sex differences in the human: studies of socioemotional development. *Archives of Sexual Behavior, 4*(4), 329–335.
Lewis, M., & Freedle, R. (1973). *Mother-infant dyad: The cradle of meaning. Communication and affect: language and thought*. P. Pliner, L. Krames and et. al. Oxford, England: Academic Press.
Lewis, M. D. (2005). Self-organizing individual differences in brain development. *Developmental Review, 25*, 252–277.
Lewis, M. D., Lamey, A. V., & Douglas, L. (1999). A new dynamic systems method for the analysis of early socioemotional development. *Developmental Science, 2*(4), 457–475.
Locke, J. L. (2001). First Communion: the emergence of vocal relationships. *Social Development, 10*(3), 294–308.
Malatesta, C. Z., Culver, C., Tesman, J. R., & Shepard, B. (1989). The development of emotion expression during the first two years of life. *Monographs of the Society for Research in Child Development, 54*(1-2), 1–104.
Mareschal, D. (2007). *Neuroconstructivism*. Oxford; New York: Oxford University Press.
Mareschal, D., & Quinn, P. C. (2001). Categorization in infancy. *Trends in Cognitive Sciences, 5*(10), 443–450.
Martin, C. L., Ruble, D. N., & Szkrybalo, J. (2002). Cognitive theories of early gender development. *Psychological Bulletin, 128*(6), 903–933.
May, E. T. (1995). *Barren in the promised land: childless Americans and the pursuit of happiness*. New York: Basic Books.
McIntyre, M. H., & Edwards, C. P. (2009). The Early Development of Gender Differences. *Annual Review of Anthropology, 38*, 83–97.
Moss, H. A. (1967). Sex, age, and state as determinants of mother-infant interaction. *Merrill Palmer Quarterly, 13*, 119–135.
Newell, K. M., Liu, Y.-T., & Mayer-Kress, G. (2003). A dynamical systems interpretation of epigenetic landscapes for infant motor development. *Infant Behavior and Development, 26*, 449–472.
Phillips, S., King, S., & DuBois, L. (1978). Spontaneous activities of female versus male newborns. *Child Development, 49*(3), 590–597.
Poeggel, G., Helmeke, C., Abraham, A., Schwabe, T., Friedrich, P., & Braun, K. (2003). Juvenile emotional experience alters synaptic composition in the rodent cortex, hippocampus, and lateral amygdala. *Proceedings of the National Academy of Sciences of the United States of America, 100*(26), 16137–16142.
Poeggel, G., Nowicki, L., & Braun, K. (2003). Early social deprivation alters monoaminergic afferents in the orbital prefrontal cortex of Octodon degus. *Neuroscience, 116*(3), 617–620.
Poulin-Dubois, D., Serbin, L. A., & Berbyshire, A. (1998). Toddlers' intermodal and verbal knowledge about gender. *Merrill Palmer Quarterly, 44*(3), 338–354.
Poulin-Dubois, D., Serbin, L. A., Eichstedt, J. A., Sen, M. G., & Beissel, C. F. (2002). Men don't put on make-up: Toddlers' knowledge of the gender stereotyping of household activities. *Social Development, 11*(2), 166–181.
Poulin-Dubois, D., Serbin, L. A., Kenyon, B., & Derbyshire, A. (1994). Infants' intermodal knowledge about gender. *Developmental Psychology, 30*(3), 436–442.
Quartz, S. R. (2003). *Learning and brain development: a neural constructivist perspective. connectionist models of development: developmental processes in real and artificial networks*. P. T. Quinlan. New York: Psychology Press: Taylor and Francis Group. 279–309.
Quinn, P. C., Yahr, J., Kuhn, A., Slater, A. M., & Pascalils, O. (2002). Representation of the gender of human faces by infants: a preference for female. *Perception, 31*(9), 1109–1121.
Roopnarine, J. L. (1986). Mothers' and Fathers' Behaviors Toward the Toy Play of their Infant Sons and Daughters. *Sex Roles, 14*(1/2), 59–68.
Roopnarine, J. L., Fouts, H. N., Lamb, M. E., & Lewis-Elligan, T. Y. (2005). Mothers' and fathers' behaviors toward their 3- to 4-month-old infants in lower, middle, and upper socioeconomic African American families. *Developmental psychology, 41*(5), 723–732.
Rubin, J. Z., Provenzano, F. J., & Luria, Z. (1974). The eye of the beholder: parents' views on sex of newborns. *American Journal of Orthopsychiatry, 44*(4), 512–519.
Sadato, N., Morita, T., Grafman, J., Ibañez, V., Deiber, M.-P., Dold, G., et al. (2008). The Role of Neuroimaging in Developmental Social Psychology. *Brain Imaging and Behavior, 2*, 335–342.
Sadeh, A., Dark, I., & Vohr, B. R. (1996). Newborns' sleep-wake patterns: the role of maternal, delivery and infant factors. *Early Human Development, 44*(2), 113–126.
Saxon, T. F. (1997). A longitudinal study of early mother-infant interaction and later language competence. *First Language, 17*, 271–281.
Schore, A. N. (1994). *Affect regulation and the origin of the self: the neurobiology of emotional development*. Hillsdale, N.J., L. Erlbaum Associates.
Schore, A. N. (2000). *The Self-Organization of the right Brain and the Neurobiology of Emotional Development. Emotional development and self organization: dynamic systems approac to emotional development*. M. D. Lewis and I. Granic. Cambridge, England: Cambridge University Press.
Schore, A. N. (2001a). Contributions from the decade of the brain to infant mental health: An overview. *Infant Mental Health Journal, 22*(1-2), 1–6.
Schore, A. N. (2001b). Effects of a secure attachment relationship on right brain development, affect regulation, and infant mental health. *Infant Mental Health Journal, 22*(1-2), 7–66.
Schulkin, J. (2003). *Rethinking Homeostasis: allostatic regulation in physiology and pathophysiology*. Cambridge: MIT Press.
Smith, P. K., & Daglish, L. (1977). Sex Differences in Parent and Infant Behavior in the Home. *Child Development, 48*(3), 1250.
Spencer, J. P., Clearfield, M., Corbetta, D., Ulrich, B., Buchanan, P., & Schoner, G. (2006). Moving toward a grand theory of development: in memory of Esther Thelen. *Child Development, 77*(6), 1521–1538.
Sterling, P. (2004). *Principles of allostasis: optimal design, predictive regulation, pathophysiology and rational therapeutics. Allostasis, homeostasis, and the costs of physiological adaptation*. J. Schulkin. Cambridge: MIT Press. pp17–64.
Sterling, P., & Eyer, J. (1988). *Allostasis: a new paradigm to explain arousal pathology. Handbook of life stress, Cognition and Health*. S. Fisher and J. Reason. New York, J: Wiley and Sons. pp629–649.
Sur, M., & Rubenstein, J. L. (2005). Patterning and plasticity of the cerebral cortex. *Science, 310*(5749), 805–810.
Swain, J. E., Lorberbaum, J. P., Kose, S., & Strathearn, L. (2007). Brain basis of early parent-infant interactions: psychology, physiology, and in vivo functional neuroimaging studies. *Journal of Child Psychology and Psychiatry, 48*(3-4), 262–287.
Swain, J. E., Tasgin, E., Mayes, L. C., Feldman, R., Constable, R. T., & Leckman, J. F. (2008). Maternal brain response to own baby-cry is affected by cesarean section delivery. *J Child Psychology and Psychiatry, 49*(10), 1042–1052.
Sweeney, J., & Bradbard, M. R. (1988). Mothers' and fathers' changing perceptions of their male and female infants over the course of pregnancy. *Journal of Genetic Psychology, 149*(3), 393–404.
Thelen, E. (1995). Motor Development: A new Synthesis. *American Psychologist, 50*(2), 79–95.
Thelen, E. (2000). Grounded in the World: Developmental Origins of the Embodied Mind. *Infancy, 1*(1), 3–28.
Thelen, E., & Corbetta, D. (2002). *Microdevelopment and dynamic systems: Application to infant motor development. Microdevelopment: Transition Processes in Development and Learning*. N. Grannot and J. Parziale. Cambridge: Cambridge University Press.
Thelen, E., Fisher, D. M., & Ridley-Johnson, R. (2002). The relationship between physical growth and a newborn reflex. *Infant Behavior & Development, 25*(1), 72–85.

Thelen, E., Schoener, G., Scheier, C., & Smith, L. B. (2001). The dynamics of embodiment: A field theory of infant perseverative reaching. *Behavioral and Brain Sciences, 24*(1), 1–86.

Thelen, E., & Smith, L. B. (1994). *A Dynamic Systems Approach to the Development of Cognition and Action*. Cambridge: MIT Press.

Thelen, E., & Smith, L. B. (1998). R. M. Lerner. *Dynamic Systems Theories. Handbook of Child Psychology: Theoretical Models of Human Development, 1*. New York: John Wiley and Sons, 563–634.

Thordstein, M., Lofgren, N., Flisberg, A., Lindecrantz, K., & Kjellmer, I. (2006). Sex differences in electrocortical activity in human neonates. *Neuroreport, 17*(11), 1165–1168.

Tronick, E. Z., & Cohn, J. F. (1989). Infant-mother face-to-face interaction: age and gender differences in coordination and the occurrence of miscoordination. *Child Development, 60*(1), 85–92.

van de Beek, C. (2005). *Prenatal Sex Hormones and Gender-Related Behavior in Infants PhD*. Universiteit Utrecht.

Weinberg, M. K., Tronick, E. Z., Cohn, J. F., & Olson, K. L. (1999). Gender differences in emotional expressivity and self-regulation during early infancy. *Developmental Psychology, 35*(1), 175–188.

Wexler, B. E. (2006). *Brain and Culture: neurobiology, ideology and social change*. Cambridge: The M.I.T. Press.

Ziabreva, I., Poeggel, G., Schnabel, R., & Braun, K. (2003). Separation-induced receptor changes in the hippocampus and amygdala of Octodon degus: influence of maternal vocalizations. *The Journal of Neuroscience, 23*(12), 5329–5336.

Ziabreva, I., Schnabel, R., Poeggel, G., & Braun, K. (2003). Mother's voice "buffers" separation-induced receptor changes in the prefrontal cortex of octodon degus. *Neuroscience, 119*(2), 433–441.

Zosuls, K. M., Ruble, D. N., Tamis-Lemonda, C. S., Shrout, P. E., Bornstein, M. H., & Greulich, F. K. (2009). The acquisition of gender labels in infancy: implications for gender-typed play. *Developmental Psychology, 45*(3), 688–701.

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