Sex Differences in Early Infancy

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ABSTRACT—*Sex-linked behaviors in infancy have generated a great deal of interest, in part because they offer a way of assessing the extent to which sexually dimorphic behaviors exist before extensive social and educational experiences. This article reviews sex differences in basic and sensory processes, social behavior, and cognitive behavior that have been reported during the 1st year of life, and discusses current knowledge about the underlying basis for these differences and the extent to which they contribute to later behavior. Careful investigation of the interaction between social and biological factors in infancy will be necessary to fully understand the nature and development of human sex differences.*

KEYWORDS—*sex differences; infant development*

Higher prenatal androgens in males than in females masculinize the genitalia, the developing neural system, and behavior (Breedlove, Cooke, & Jordan, 1999; Hines, 2002, 2004). Hormonally dependent, sex-specific changes in the ultrastructure of the developing central nervous system (such as cell proliferation, cell death, patterns of cell migration, dendritic branching; MacLusky, Bowlby, Brown, Peterson, & Hochberg, 1997) ultimately affect volumes of the hypothalamus, amygdala, and hippocampus—brain regions that are neural substrates of sexual behavior, aggression, learning, and memory (Arnold & Gorski, 1984; MacLusky & Naftolin, 1981). Through these effects on complex biological processes, androgen levels during critical periods in early development are thought to contribute to the

between- and within-sex variability in human social and cognitive behavior (Collaer & Hines, 1995).

In other primates, hormone-dependent behavioral predispositions are shaped by early social experiences (Wallen, 1996), and sex-typed physical phenotypes at birth prompt different social response to male and female infants (such as the frequency of anogenital inspection; Goy, Bercovitch, & McBrair, 1988). Similarly, androgen-dependent virilization of external genitalia in human infants supports gender labels, social categories that activate a lifelong process of gender socialization that extends from gender-typed toys for newborns (Pomerleau, Bolduc, Malcuit, & Cossette, 1990) to the daily modeling and reinforcement of "gender-appropriate" behavior (Bussey & Bandura, 1999). Bidirectional relations between sex-linked biological and social processes also exist in early infancy. For example, at birth, girls show higher length-to-weight ratios than boys (Thomas, Peabody, Turnier, & Clark, 2000), a less prominent chin, and anteriorly narrower dental arcade (Schutkowski, 1993). Consistent with this, adults perceive infant girls as smaller, softer, and finer featured (Rubin, Provenzano, & Luria, 1974) and handle boys more roughly than girls (Lewis, 1972). These subtle differences in adult–infant interactions are not without consequence: Other findings suggest that boys' higher rates of head injuries in the first 3 months primarily result from being dropped (Greenes, Wigotsky, & Schutzman, 2001).

EMERGING SEX DIFFERENCES?

Evidence from research on older children and adults supports the masculinizing effects of prenatal testosterone on social and cognitive behavior (such as empathy, aggression, play styles and toy preferences, and spatial abilities; Collaer & Hines, 1995; Hines, 2010). If infants have sex-linked dispositions that represent "seeds" of later behavior, then a reasonable hypothesis is that male and female infants may differ in temperament, in sensitivity to social stimuli, and in cognitive processes that support the development of the male advantage in spatial ability (Geary, 2006; McIntyre & Edwards, 2009). Of course, the expected sex effects in early infancy might be smaller than those later in

development, when expressed behavior presumably reflects the further influence of experiential factors.

Basic and Sensory Processes

One suggestion is that biological influences associated with the sexual differentiation of behavior should have no direct effects on basic or sensory processes associated with infant survival (Benenson, Philippoussis, & Leeb, 1999). Yet, one recent explanation for the greater infant mortality and complication rates in males is that exposure to higher prenatal androgen levels enhances fetal growth and inhibits lung development (Mage & Donner, 2006). Other sex differences in infant physiology appear necessary to support adult sex-linked behavior. Plasma testosterone levels in infant boys but not girls approach the early puberty male range before falling to typical low childhood values around 6 months of age (Andersson et al., 1998; Forest, Sizonenko, Cathiard, & Bertrand, 1974). As in adolescence, this postnatal increase in testosterone is critical for the normal development of male genitalia (Main, Schmidt, & Skakkebaek, 2005), such that higher levels of testosterone at 3 months of age predict greater penile growth in early childhood (Boas et al., 2006). Other findings from detailed analyses of movement and coordination at 6, 12, and 18 weeks are consistent with the later female advantage in fine motor skill and the male advantage in gross motor activity (Piek, Gasson, Barrett, & Case, 2002). An early female advantage in fine motor behavior is also suggested by more accurate imitation of finger movements in neonatal girls than in boys (Nagy, Kompagne, Orvos, & Pal, 2007). Finally, consistent with known sexually dimorphic pain processes in adults (Craft, Mogil, & Aloisi, 2004), research measuring facial expressivity associated with a heel prick suggests that neonatal girls are more sensitive to painful stimuli (Guinsburg et al., 2000), and properties of infant cries at 2 weeks to 6 months are consistent with greater pain reactivity in girls than in boys (Fuller, 2002). The auditory system is also sexually dimorphic in infancy and adulthood (McFadden, 1998), such that transient-evoked otoacoustic emissions—sounds produced in the inner ear in response to acoustic stimuli—are weaker in males than in females. However, in this instance, the significance of the sex difference in sensory processing for adult behavior is unknown.

Sex differences have been reported in several facets of vision, which are notable given that research on sex-linked social and cognitive processes in infancy depends largely on measures of visual attention. During the first 4–6 months of life, infant girls precede boys in the maturation of visual acuity (Held, Shimojo, & Gwiazda, 1984; Makrides, Neumann, & Gibson, 2001), stereopsis (Birch, Gwiazda, & Held, 1982), and evoked responses to changes in visual pattern (Malcolm, McCulloch, & Shepherd, 2002). Sex differences in the emergence of stereopsis may be due to girls' better vergence of the eyes (Horwood & Riddell, 2008) and, in boys, appears to be correlated negatively with plasma testosterone levels (Held, Bauer, & Gwiazda, 1988). Different rates of stereopsis development could account for sex dif-

ferences observed on some physical reasoning tasks (Baillargeon, 1998; Baillargeon & DeVos, 1991). For example, when the interpretation of a three-dimensional visual display requires detection of the relative location of objects in the depth plane (e.g., requires infants to detect whether two objects are aligned in the depth plane so that one sits on top of the other), young girls between 4 and 5.5 months are more likely than young boys to correctly interpret support relations (Baillargeon, 1998). A few sex differences in visual processing favor boys: At 2 months, they demonstrate greater contrast sensitivity, and during the first 3 months, they demonstrate better accommodative responses (Dobkins, Bosworth, & McCleery, 2009; Horwood & Riddell, 2008). In sum, early sex differences in maturation of visual processes are important for interpretation of three-dimensional visual displays. However, these sex differences are transient and appear to have no long-term consequences for behavior.

Social Behavior

Several lines of research are consistent with small sex differences in emerging personality and social domains. A meta-analyses of gender differences in temperament found that, compared to boys, infant girls are better able to inhibit responses and show greater sensitivity to environmental changes, greater fearfulness, and lower activity levels (Else-Quest, Hyde, Goldsmith, & Van Hulle, 2006). Infant girls may also show greater responsiveness to social stimuli, such as the maternal face, sound, or touch. For example, compared to males, female newborns score higher in global ratings of cuddliness (Benenson et al., 1999), show more orientation to a face or voice (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000; Osofsky & O'Connell, 1977), and, like older infant girls (Mundy et al., 2007), exhibit longer eye contact with an experimenter (Hittelman & Dickes, 1979). Sex differences in the incentive value of social stimuli are also consistent with findings that infant girls show stronger visual preferences for a doll (i.e., an object with human attributes) than for a toy truck (Alexander, Wilcox, & Woods, 2009) than infant boys. In contrast, boys shortly after birth show stronger visual preferences for a mechanical mobile than for a face (Connellan et al., 2000) and, like much older boys, in the 1st year of life they show more visual preferences for balls, vehicles, and a group of figures than for a solitary figure (Alexander et al., 2009; Benenson, Duggan, & Markovits, 2004; Campbell, Shirley, & Heywood, 2000).

Sex differences in affective processing and response are also reported in infancy. Infant girls, like older females, show better discrimination of emotional expressions than their male counterparts (McClure, 2000). In studies of contagious crying in neonates, arguably a primitive precursor to empathic reactions (Hoffman, 1973), girls cry longer than boys in response to recordings of a cry from a female infant (Sagi & Hoffman, 1976; Simner, 1971). At 2.5 months of age, girls show more expres-

sions of joy to the appearance of mother than boys do (Cossette, Pomerleau, Malcuit, & Kaczorowski, 1996), and after 6 months of age, girls appear more responsive to maternal vocalizations as defined by a behavior change appropriate to the mother's initiation (Gunnar, & Donahue, 1980). Girls at 3–4 months of age are also more distressed by maternal "still face," as defined by more extreme levels of distress, longer periods of looking away, and more frequent arching of body (Mayes & Carter, 1990).

Yet, there are notable inconsistencies in the literature. One study found no sex differences in neonatal eye contact (Leeb & Rejskind, 2004), and in research on a relatively large number of infants at 6 months of age ($n = 81$), the pattern of social responsiveness we described above was reversed: Boys, not girls, showed more joy, greater looking time at mother, more anger in response to the still face of mother, and more gesturing to be picked up (Weinberg, Tronick, Cohn, & Olson, 1999). One study observed no significant gender differences in contagious crying in a relatively large sample of infants at 1–9 months of age (Geangu, Benga, Stahl, & Striano, 2010). Moreover, the direction of the effect was reversed such that cry time, intensity, and facial expressions of distress were significantly greater in boys than girls. Finally, a recent meta-analysis of infant response to maternal still face found no main effects of gender (Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009). Future research will need to identify the factors (such as socialization or experimenter bias) that contribute to this variability in the direction and the magnitude of the effects.

Cognitive Behavior

There are two domains in which sex differences have been observed reliably and/or the observed differences appear to be related to later emerging sex differences: mental rotation and event mapping. Consistent with the robust male advantage reported in adolescents and adults on mental rotation tasks (MRTs; Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995), sex differences in MRT performance have been observed in 3- to 5-month-old infants using looking-time measures (Moore & Johnson, 2008; Quinn & Liben, 2008). Researchers familiarized infants with an object and measured subsequent looking to a rotated or mirror image of that object. Longer looking to the mirror image was taken as evidence of mental rotation; boys but not girls demonstrated longer looking to the mirror than to the rotated image. In a subsequent study, 3-month-old boys (but not girls) demonstrated a preference for the rotated over the mirror image (Moore & Johnson, 2011). This familiarity preference was interpreted as a reflection of greater task difficulty for the younger infants. If we consider these MRT paradigms as analogous to those used with children and adults, then these findings reflect early emergence of sex differences in mental rotation abilities. However, because the MRTs used with the infants employed only mirror images (which is problematic for young children) and results obtained in children younger than 13 years tend to be mixed (Grimshaw, Sitarenios, & Finegan, 1995;

Kerns & Berenbaum, 1991; Linn & Petersen, 1985; Voyer et al., 1995), further investigation of early emerging sex differences in MRTs is warranted.

In an event-mapping task, infants see a test event composed of an occlusion sequence followed by a no-occlusion display. For example, infants see a ball and a box move to opposite sides of an occluder; next, the occluder is lowered to reveal one ball (Figure 1A). Boys detect the inconsistency between the initial ball–box event and the final one-ball display (they show prolonged looking to the one-ball display) at 10.5 months, whereas girls first detect this inconsistency at 11.5 months (Wilcox, 2007). When infants are given clues as to the objects' occluded trajectories prior to the occlusion event, boys succeed at 7.5 months and girls at 9.5 months (Wilcox, 2003). Finally, researchers have reported similar sex differences favoring boys in other event-mapping tasks (Schweinle & Wilcox, 2004).

Successful performance on event-mapping tasks requires infants to extract the simple structure of the initial occlusion sequence—the number of distinct objects and their spatiotemporal coordinates—and map this onto the final display (Figure 1B). Boys may be more likely than girls to identify the trajectories of moving occluded objects and, hence, may be more likely to extract the simple structure, a hypothesis supported by a recent eye-tracking study assessing infants' scanning of the initial event and final display (Wilcox, Alexander, Wheeler, & Norvell, in press). (Note that eye-tracking technology, which offers a more sensitive measure of performance than duration of looking methods, has revealed sex differences favoring boys at an earlier age.) At 9.5 months, boys scanned both sides of the screen when the objects were fully occluded, shifting attention as the objects moved left to right (or right to left) behind the screen (they shifted attention in accord with the objects' trajectories, even though the objects were out of view). In contrast, girls focused attention on the side of the screen behind which an object most recently disappeared, rarely shifting attention to the other side as the occlusion interval progressed (they failed to follow occluded trajectories). In addition, boys were more likely than girls to detect an inconsistency between the ball–box event and the one-ball display—they visually searched for the missing box at the center of the platform when the occluder was lowered. Finally, infants (mostly boys) who tracked the trajectory of the objects as they moved behind the screen during the occlusion sequence were more likely to scan the center of the platform for the missing box when the screen was lowered, suggesting that the ability to identify occluded trajectories facilitates extraction of the simple structure of the event and subsequent mapping. Sex differences were not observed at 4 months: Both sexes performed like 9.5-month-old girls who failed to map the ball–box event onto the one-ball display.

Sex differences in event mapping may be related to those observed on object-processing tasks later in development. For example, in late infancy, human and monkey males show better performance than females on object reversal tasks, which require
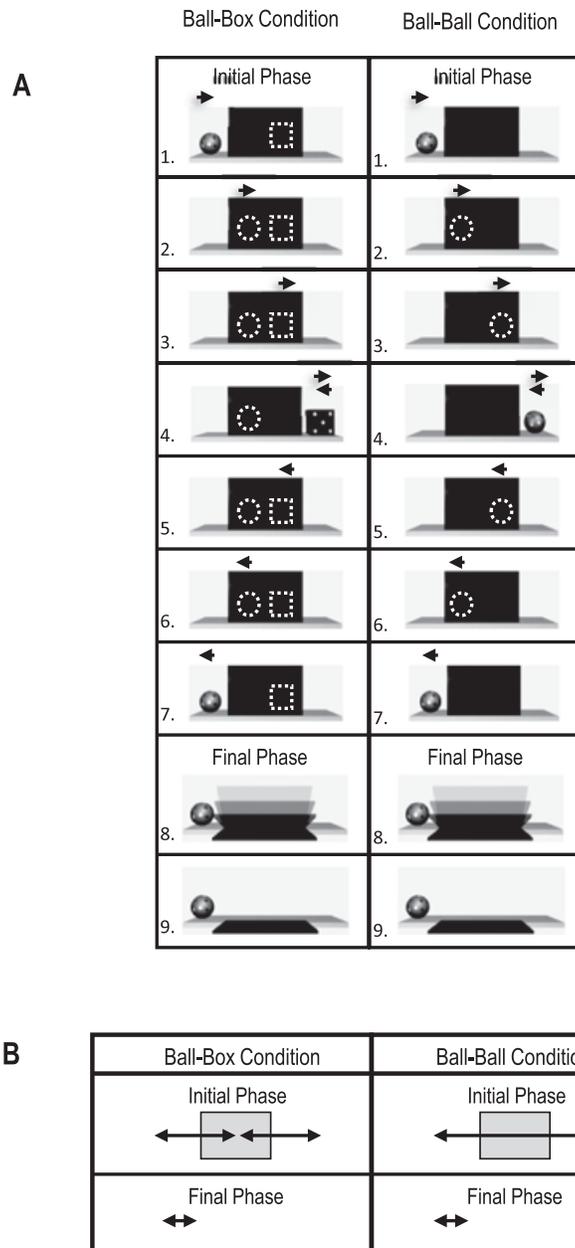
Ball-Box Condition   Ball-Ball Condition

Figure 1. (A) An example of an event-mapping task involving a ball–box and ball–ball test event. In the initial phase of the test event, the objects moved back and forth behind the screen. The dotted shapes represent the location of the object(s) when behind the screen and was not visible to the infant. The final phase consisted of a single ball sitting on the platform. (B) The simple structure of the ball–box and ball–ball events.

infants to keep track of specific objects and their spatiotemporal coordinates over time. These differences have been linked to faster rates of maturation in the male orbital prefrontal cortex induced by the presence of androgens (for a review, see Overman, Bachevalier, Schuhmann, & McDonough-Ryan, 1997). In older children and adults, males outperform females on tasks that require the extraction and manipulation of the spatial structure of visual displays (Levine, Huttenlocher, Taylor, & Langrock,

1999; Linn & Petersen, 1985), particularly when the displays include partially occluded objects (Voyer et al., 1995). Further research is needed to determine the extent to which sex differences in event mapping and object reversal, which appear to be transient, are related to each other and to later emerging sex differences in processing of the spatial structure of visual displays (Levine et al., 1999; Linn & Petersen, 1985; Voyer et al., 1995).

Finally, sex differences have been reported in several other domains, including habituation behaviors (Creighton, 1984; Tighe & Powlison, 1978), perception of pictorial cues (Kavšek, 2003, 2004), categorization (Arterberry & Bornstein, 2002), imitation of propulsive motion (Benenson, Tennyson, & Wrangham, 2011), perception of number (Moore & Cocas, 2006; Strauss & Curtis, 1981), and components of linguistic processing (Friederici et al., 2008; Lany & Gomez, 2008; Shucard, Shucard, & Thomas, 1987). However, many of these results are difficult to interpret, have not been replicated, and/or have inconsistent outcomes across studies. Interpretation of these sex differences awaits further evidence.

FUTURE DIRECTIONS

Sex differences in early infancy suggest that the seeds of sex-linked behavior are sown in very early life. The application of technologies such as eye-tracking and noninvasive measures of brain activation like optical imaging may be useful in developing a more precise understanding of the perceptual features of objects (including shape and movement) and the brain systems that influence infants' affective and cognitive responses to social and nonsocial stimuli. Future identification of the building blocks of sex-linked behavior may also be enhanced by including the measurement of behavior at times in development before and after the onset of sex differences. For example, in eye-tracking research of infants 3–4 months of age who showed no sex-linked visual preferences, higher androgen levels in boys predicted stronger visual preferences for male-typical stimuli, such as a ball (Alexander, Wilcox, & Farmer, 2009). The relation between biological factors and undifferentiated infant behavior (or "pre-emergent" sex-linked behavior) observed in this research suggests that androgens influence sex-linked behavior in infant boys prior to the known effects of differential reinforcement on the expression of behavior. Finally, the interaction between biological and social factors in later development has been informed by findings from studies of endocrine disorders. Girls exposed to androgen levels more typical of the prenatal hormonal environment of boys because of congenital adrenal hyperplasia (Carson et al., 1982), for example, show stronger preferences for toys and playmates that boys typically prefer (Berenbaum & Hines, 1992; Hines & Kaufman, 1994); better performance on targeting ability, a motor task that typically shows a large male advantage (Collaer, Brook, Conway, Hindmarsh, & Hines, 2009); and stronger male-typical personality traits, as indicated by levels of aggression and interest in infants (Mathews, Fane, Conway,

Brook, & Hines, 2009; Pasterski et al., 2007). Although research on older affected children suggests that this increased behavioral masculinization is not attributable to socialization (Pasterski et al., 2005), investigations of sex-linked behavior in infants with endocrine disorders would provide a stronger test of the biological and social influences on gender development.

It may also be useful to broaden variables of interest to include sex-linked physiological processes that may represent an immature form or component part of a more complex behavior expressed in later development. Findings of fewer basic oral movements such as rhythmical mouth movements and lingual movements during sucking in male neonates (Miller, Macedonia, & Sonies, 2006), for example, has suggested that they may contribute to sex differences in language development, including the greater incidence of speech deficits in boys (Tromblin et al., 1997). Findings that female neonates are more responsive to sweetened formula (Nisbett & Gurwitz, 1970), a taste that elicits a reflexive "smile" (Erickson & Schulkin, 2003), and show greater auditory sensitivity (Cassidy & Ditty, 2001; Kei, McPherson, Smyth, Latham, & Lascher, 1997) may inform an understanding of sex differences in emotional response or language.

More than 10 years ago, researchers noted that few investigators specifically examined sex differences in infancy and that most investigations were not hypothesis driven (Weinberg et al., 1999). Although today these observations remain largely true, increasing evidence of a role for biological factors in the development of human behavior, including disorders with sex differences in prevalence rates (Knickmeyer & Baron-Cohen, 2006; Martel, Klump, Nigg, Breedlove, & Sisk, 2009), will likely encourage researchers to examine carefully sex differences in infant development and their contribution to later behavior.

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