AN-10 Sex differences in juvenile mammals

Introduction: A Framework for Mammalian Sex Differences

The study of sex differences in juvenile mammals provides a vital lens through which to view the interplay of evolutionary pressures, neurobiological development, and environmental socialization. For researchers and practitioners seeking to understand how males and females can best navigate shared social structures—from families and couples to complex organizations and societies—it is necessary to deconstruct developmental differences with extreme rigor. The manifestation of sex differences prepares immature organisms for the distinct reproductive and social demands of adult life, yet translating these findings to humans requires caution to avoid over-determinism.

To achieve a nuanced understanding of this highly contested field, this report systematically evaluates the empirical data across three interacting layers. The first layer is *physiology*, which encompasses the measurable genetic, neuroendocrinological, and cellular substrates that organize the developing brain. The second layer is *behaviour*, which is best conceptualized through statistical distributions of overlapping populations in traits such as play styles, object preference, risk-taking, and spatial navigation. The third layer is *culture* (or social ecology), which encapsulates the variable, external overlay of socialization, parental reinforcement, and peer dynamics that mold biological predispositions.

This exhaustive review prioritizes peer-reviewed primary literature, systematic reviews, and meta-analyses to examine the development of juvenile mammals. It presents the strongest evidence surrounding contemporary controversies, explicitly distinguishes population averages from individual capacities, and extracts robust implications for human living arrangements while strictly avoiding the naturalistic fallacy—the assumption that a biologically "natural" behavior is inherently morally "good" or socially desirable.

Layer 1: Physiology (The Measurable Substrate)

The biological foundation of mammalian sex differences is laid down early in fetal development. The prevailing framework for understanding this process is the organizational-activational hypothesis, heavily supported by the seminal work of Goy, Resko, and McEwen (1980) on rhesus macaques (*Macaca mulatta*)[1]. This paradigm asserts that prenatal steroid hormones permanently organize the neural circuits underlying sexually dimorphic behaviors, which are subsequently activated by the hormonal milieu of puberty and adulthood[1].

Prenatal Androgens and Brain Organization

In mammalian embryonic development, the presence of the *SRY* gene on the Y chromosome initiates the differentiation of the testes, which subsequently secrete high levels of androgens during a critical perinatal window[4]. This androgen surge is responsible for both the masculinization (the active promotion of male-typical neural architecture) and defeminization

(the suppression of female-typical neural architecture) of the developing brain[4]. In classic experiments, Goy and Resko (1972, *Recent Progress in Hormone Research*) demonstrated that treating pregnant female rhesus macaques with testosterone propionate between gestational days 40 and 90 resulted in female offspring that exhibited heavily masculinized juvenile behaviors, including increased rates of mounting and rough-and-tumble play[2]. Crucially, they found that both aromatizable androgens (like testosterone, which can be converted to estrogen) and nonaromatizable androgens (like dihydrotestosterone) were equally effective in masculinizing primate behavior. This established that the androgen receptor pathway itself is the primary mediator of brain sexual differentiation in anthropoid primates[2].

In rodents, however, the mechanisms of sexual differentiation frequently rely on localized neurochemical conversions. Testosterone that crosses the blood-brain barrier is often converted by the aromatase enzyme into estradiol, which then acts to prevent programmed cell death (apoptosis) in specific brain nuclei[1]. For example, the sexually dimorphic nucleus of the preoptic area (SDN-POA) is protected from apoptosis by early estradiol exposure in males. As a direct result, the adult male SDN-POA is five to seven times larger in volume and cell number than the female equivalent[4].

The Amygdala, Endocannabinoids, and Microglia

Recent breakthroughs in neurobiology have revealed precisely how these early hormonal signals translate into complex juvenile social behaviors. The medial amygdala (MeA) is a highly sexually differentiated brain region that acts as the primary driver of sex differences in social play[8]. VanRyzin, Marquardt, and McCarthy (2019, *Neuron*) identified a novel mechanism of brain masculinization involving microglia, the brain's resident immune cells.

During a critical perinatal window in rats, high fetal androgen levels trigger a localized increase in endocannabinoid tone within the neonatal male amygdala[9]. This surge in endocannabinoid signaling induces microglia to become highly phagocytic (active in engulfing cellular material)[9]. VanRyzin et al. observed that these active microglia preferentially engulf and eliminate viable newborn astrocytes in the male brain[9]. In developing females, who lack the androgen-driven endocannabinoid surge, microglial phagocytosis is significantly reduced, allowing a much greater number of astrocytes to survive into the juvenile period[9].

This difference in cellular density dictates behavioral output. VanRyzin et al. (2019) demonstrated that the higher astrocyte density in the female juvenile amygdala suppresses neuronal excitation. Conversely, the male amygdala, having been cleared of these astrocytes by early microglial phagocytosis, experiences heightened neuronal excitation during social encounters[9]. This specific neural architecture directly facilitates the higher rates of rough-and-tumble play characteristic of juvenile male rats. Blocking this complement-dependent microglial phagocytosis in newborn males prevented the masculinization of their play behavior, confirming a causal link between early neuroimmune activity and later behavioral sex differences[9].

The Controversy of Brain "Dimorphism"

While localized, hormone-driven structural differences (such as those in the MeA and SDN-POA) are robustly documented in rodent and non-human primate models, the extent to

which the human brain can be classified as "sexually dimorphic" remains highly controversial. The leading critic of the dimorphic brain paradigm is neurobiologist Lise Eliot.

In a comprehensive synthesis of human brain studies, Eliot et al. (2021, *Neuroscience and Biobehavioral Reviews*) reviewed three decades of human MRI and postmortem data, emphasizing meta-analyses and large-sample studies[11]. Eliot and colleagues argue that human male and female brains are not categorically distinct but rather exist on a highly overlapping, mosaic continuum. They acknowledge that male brains are, on average, 11% larger than female brains—a volumetric difference that is present from birth and scales with general body size differences[12]. However, they demonstrate that when researchers statistically control for total brain volume, the purported sex differences in white-to-gray matter ratios, intra- versus interhemispheric connectivity, and regional cortical volumes largely vanish[12].

Independent of brain size, Eliot et al. (2021) concluded that biological sex explains only about 1% of the total variance in human brain structure[12]. Furthermore, task-based functional MRI (fMRI) studies have historically failed to find reproducible, sex-specific activation differences in spatial, verbal, or emotional processing, largely due to high rates of false discovery in underpowered studies[12]. Eliot argues that multivariate sex/gender prediction algorithms perform poorly across diverse populations, rendering the concept of a strictly "male brain" or "female brain" scientifically obsolete[12].

This controversy establishes a critical boundary condition in the literature: physiological mechanisms that tightly dictate specific fixed-action patterns in rodents do not neatly map onto the human neocortex. The massive expansion of the human cortex allows for unprecedented behavioral plasticity. Therefore, physiological sex differences in humans operate as subtle probabilistic biases rather than binary, hardwired neural categories.

Layer 2: Behaviour (Statistical, Overlapping Distributions)

Behavioral sex differences in juveniles must be understood statistically. Rather than viewing traits as exclusively male or female, researchers measure the mean differences between two highly overlapping normal distributions. A male advantage in a specific behavior does not preclude a large percentage of females from exhibiting higher levels of that behavior than the average male; it merely indicates a shift in the population mean.

Rough-and-Tumble Play (RTP) and the Social Brain

Play is a complex, socially mediated behavior conserved across nearly all mammalian species. In the vast majority of these species, juvenile males engage in significantly more frequent, aggressive, and vigorous rough-and-tumble play (RTP) than females[13]. In a meta-analytic review of human childhood play, Harbin (2023, *International Journal of Undergraduate Research and Creative Activities*) confirmed that boys are statistically more likely to engage in physical, solitary, and aggressive forms of RTP, whereas girls exhibit a higher propensity for cooperative, collaborative, and verbally expressive play[13].

RTP is not simply an outlet for excess physical energy; it serves a profound neurodevelopmental purpose. In laboratory rats, RTP typically involves a complex sequence of

attack, defense, and counterattack, centered on gaining physical access to a partner's nape[18]. Pellis, Pellis, and colleagues (2023, *Neuroscience and Biobehavioral Reviews*) have championed the "training for the unexpected" hypothesis regarding the evolutionary function of play fighting[18]. They argue that RTP does not train specific motor actions, but rather facilitates the development of the prefrontal cortex and associated executive functions[18]. By deliberately handicapping themselves and allowing themselves to lose control during play (e.g., executing role reversals such as pinning and being pinned), juvenile mammals learn to cope with sudden physical and emotional unpredictability[18].

The developmental necessity of RTP is highly sex-specific. Marquardt, VanRyzin, and McCarthy (2023, *Frontiers in Behavioral Neuroscience*) utilized a novel cage apparatus to subject juvenile rats to social play deprivation (SPD) while permitting visual, auditory, and olfactory contact[21]. This isolated the specific variable of physical play fighting. The researchers found that play deprivation yielded enduring, sex-specific socio-cognitive deficits in adulthood, primarily impacting males. Males deprived of juvenile play exhibited decreased sexual behavior, hypersociability (an inability to interpret social cues accurately), and a marked increase in inappropriate aggressiveness as adults[21]. Conversely, play deprivation had virtually no effect on these socio-sexual measures in female rats[21]. This provides compelling evidence that the male mammalian brain uniquely requires the physical friction and social negotiation inherent in rough-and-tumble play during the juvenile period to calibrate appropriate adult impulse control and social competence.

Object versus Social Interest

A deeply entrenched debate in developmental psychology concerns whether male and female infants possess innate differences in their visual interest in the physical (mechanical) versus the social (human) world.

Connellan, Baron-Cohen, et al. (2000, *Infant Behavior & Development*) famously tested 102 human neonates (less than 24 hours old) to determine if sex differences exist prior to cultural socialization[23]. The infants were presented with a social stimulus (a human face) and a physical-mechanical stimulus (a suspended mobile). The study reported that male neonates looked longer at the mechanical mobile, while female neonates looked longer at the human face, leading the authors to conclude that female superiority in sociability is biological in origin[23].

However, this finding has faced severe replication challenges and is heavily contested. Escudero, Robbins, and Johnson (2013) utilized precise eye-tracking technology to measure the visual attention of young infants and found no sex-related preferences; both male and female infants demonstrated a robust general preference for human faces over mechanical objects (such as toy cars)[25]. More definitively, a systematic review and meta-analysis of 31 studies (comprising 40 experiments and 1,936 neonates) found no significant gender difference in visual fixation on human faces within the first month of life (*Hedges' g* = 0.076, p = 0.321)[25]. While the meta-analysis noted that female neonates showed slightly higher total orientation scores to both animate and inanimate stimuli ($g = 0.279$ and $g = 0.242$, respectively)—potentially reflecting faster overall neurological maturation at birth—the data

wholly refuted the claim of an innate, sex-specific divergence in social versus mechanical perception[25].

Toy Preferences: Evolutionary Continuity and Congenital Adrenal Hyperplasia (CAH)

Despite the collapse of the neonatal object-vs-face dichotomy, sex differences in specific *toy preferences* later in infancy and childhood are highly robust and appear biologically mediated. Human boys consistently prefer transportation and construction toys (e.g., trucks, blocks), while girls prefer dolls and plush toys. Alexander (2009, *Archives of Sexual Behavior*) utilized eye-tracking on 30 infants aged 3 to 8 months and found significant visual preferences for sex-linked toys prior to the onset of gender identity; infant girls showed a massive visual preference for a doll over a truck ($d > 1.0$), while boys showed a greater number of visual fixations on the truck ($d = 0.78$)[27].

To determine if these preferences are an artifact of human gender socialization, researchers tested non-human primates. Alexander and Hines (2002, *Evolution and Human Behavior*) presented human gender-stereotyped toys to 63 vervet monkeys (*Cercopithecus aethiops sabaeus*)[28]. Male vervets spent significantly more time in contact with masculine toys (a car and a ball), while female vervets spent significantly more time with feminine toys (a doll and a pot)[28]. This groundbreaking study was successfully replicated using a true free-choice preference paradigm by Hassett, Siebert, and Wallen (2008, *Hormones and Behavior*) in a troop of 135 rhesus monkeys (with a sample of 34 juveniles analyzed)[29]. Hassett et al. found that male macaques showed a strong, consistent preference for wheeled toys, while females showed greater variability and flexibility, interacting with both plush and wheeled toys—exactly mirroring the patterns seen in human children[29]. Because monkeys are exempt from human cultural socialization, these results suggest that toy preferences stem from hormonally influenced sensory and motor biases for specific physical affordances (e.g., mechanical movement versus nurturing/cradling affordances)[28].

In humans, the strongest evidence for the hormonal basis of toy preference comes from pediatric endocrinology. Congenital Adrenal Hyperplasia (CAH) is a genetic disorder resulting in unusually high levels of prenatal adrenal androgens[33]. Pasterski et al. (2005, *Child Development*) assessed toy choices in 81 children aged 3 to 10 years with CAH (43 girls, 38 boys) compared to 72 unaffected siblings[33]. Girls with CAH exhibited heavily masculinized toy choices, preferring boy-typical toys significantly more than unaffected girls[33]. Crucially, the researchers coded parental behavior during play sessions. They discovered that parents provided *more* positive feedback to CAH girls for playing with feminine toys than they did for unaffected girls[34]. This indicates that the CAH girls' masculine preferences persisted despite active cultural socialization to the contrary, providing powerful evidence that prenatal androgen exposure overrides postnatal parental socialization in determining early play preferences[34].

Learning Styles and the Developmental Effect of Same-Sex Models

Biological predispositions also influence how juveniles learn from adults. In wild chimpanzees (*Pan troglodytes*), Lonsdorf et al. (2014, *PLoS One*) documented early sex differences in the

acquisition of motor skills and social behavior. The study found that juvenile female chimpanzees spend significantly more time observing their mothers and acquiring complex tool-use behaviors (such as termite fishing) than juvenile males, who demonstrate earlier spatial independence and prioritize physical play over skill acquisition[36].

In humans, this selective social learning is heavily influenced by prenatal hormones. Pasterski et al. (2015) demonstrated that girls with CAH, who were exposed to high prenatal androgens, show reduced imitation of female models choosing particular objects compared to unaffected girls[39]. This suggests that prenatal androgen exposure alters the processes involved in the *self-socialization* of gendered behavior. High androgen exposure appears to reduce the salience of same-sex models for females, meaning that biology dictates not only what a child is interested in, but *who* they look to for behavioral cues and learning[39].

Exploration, Risk, Spatial Navigation, and Dispersal

Across mammalian species, juvenile males generally exhibit higher levels of physical risk-taking and environmental exploration. Byrnes, Miller, and Schafer (1999, *Psychological Bulletin*) conducted an exhaustive meta-analysis of 150 studies comparing risk-taking in human males and females[40]. They found that males took greater risks in 14 out of 16 categories, with nearly half of the categories yielding an effect size greater than 0.20 (indicating greater risk-taking in males)[40]. The gender gap in physical and intellectual risk-taking was significant, though it fluctuated with age and showed signs of narrowing slightly over historical time[40].

Directly related to environmental exploration is the development of spatial navigation abilities. Voyer, Voyer, and Bryden (1995, *Psychological Bulletin*) conducted a meta-analysis of 286 effect sizes on spatial abilities[43]. They established that the male advantage in spatial cognition, particularly in three-dimensional mental rotation tasks, represents one of the most robust cognitive sex differences documented in the literature[43]. This advantage is not present at birth; it emerges as a small effect during childhood and expands into a moderate-to-large effect size during adolescence[43]. A subsequent meta-analysis by Lauer et al. (2019, *Psychological Bulletin*) comprising 303 effect sizes from 30,613 children confirmed this developmental trajectory[45]. Animal models corroborate these findings, demonstrating that spatial memory and navigation are highly sensitive to the organizing effects of perinatal testicular hormones[46].

Evolutionarily, these male biases toward physical risk, spatial mapping, and rough play correspond to mammalian patterns of juvenile dispersal. Lawson Handley and Perrin (2007, *Molecular Ecology*) reviewed mammalian dispersal systems, noting that sex-biased dispersal is almost ubiquitous as a mechanism to prevent inbreeding and reduce kin competition[48]. In the vast majority of mammalian species, females are philopatric (remaining in their natal territory to form kin-based cooperative networks), while juvenile males are forced to disperse over long, risky distances to locate new breeding territories[48]. The neurobiological predisposition of males toward physical risk, spatial navigation, and physical competition aligns seamlessly with the evolutionary necessity of juvenile male dispersal.

Domain	Finding	Key Source	Meta-Analytic

			Effect Size / Conclusion
Brain Anatomy	Minimal structural dimorphism independent of volume	Eliot et al. (2021)[12]	Sex explains ~1% variance in brain structure.
Toy Preference	Biological bias for object features in infancy	Alexander (2009)[27]	$d > 1.0$ (infant female doll bias); $d = 0.78$ (male truck bias).
Parenting	Minimal gender-differentiated control	Endendijk et al. (2016)[50]	$d = 0.08$ (Control); $d = 0.03$ (Autonomy support).
Spatial Ability	Male advantage in mental rotation	Voyer et al. (1995); Lauer et al. (2019)[43]	Small effect in childhood; moderate/large by adolescence.
Neonatal Gaze	No innate social vs. object gaze difference	Escudero et al. (2013)[25]	$g = 0.076$ ($p = 0.321$), refuting older claims.
Risk-Taking	Male advantage in physical/intellectual risk	Byrnes et al. (1999)[40]	Males take greater risks in 14 of 16 categories.

Layer 3: Culture (The Variable Overlay)

Culture acts as an environmental amplifier or dampener of biological predispositions. A prevailing theory in modern sociology is that sex differences in children are primarily driven by "gender-differentiated parenting"—the idea that parents subconsciously treat boys and girls differently, thereby engineering behavioral gaps.

To rigorously test this hypothesis, Endendijk et al. (2016, *PLoS ONE*) conducted a massive meta-analysis of 126 observational studies encompassing 15,034 families across post-industrial societies[50]. The researchers specifically focused on *observed* parental control and autonomy-supportive strategies, explicitly avoiding the bias of self-report questionnaires[50]. The findings dramatically challenged the narrative of heavy parental socialization regarding

behavioral control. The meta-analysis revealed that differences in the parenting of boys versus girls are virtually non-existent[50]. Parents were found to be slightly more controlling with boys than with girls, but the effect size was negligible (d = 0.08)[50]. Furthermore, there was zero overall effect for gender-differentiated autonomy support (d = 0.03)[50]. While parents' implicit gender stereotypes or subtle linguistic choices might vary in micro-interactions, the macro-level behavioral control and autonomy granted to boys and girls in post-industrial societies is statistically equivalent[50].

This data leads to a profound insight: prominent behavioral sex differences in human juveniles (such as boys' higher rates of rough-and-tumble play or girls' higher rates of prosocial play) emerge *in spite of* relatively egalitarian parenting practices. These differences are largely driven by the self-socialization of biological predispositions, where children seek out activities, peers, and same-sex adult models that align with their innate hormonal and neurodevelopmental biases.

Averages vs. Individuals: The Statistical Reality

A persistent source of friction in discussions of sex differences is the conflation of population averages with individual determinism. It is a statistical certainty that male and female mammalian juveniles exhibit measurable differences in mean behaviors (e.g., spatial mental rotation, rough-and-tumble play, physical aggression). However, these traits exist on a normal distribution (a bell curve).

Because the distributions of male and female behaviors heavily overlap, the variance *within* a single sex is usually much larger than the variance *between* the sexes. For instance, while the average juvenile male macaque prefers a wheeled toy more than the average female macaque, there is significant flexibility; individual females interact with wheeled toys, and individual males interact with plush toys[30]. In humans, a moderate effect size (e.g., d = 0.50 in spatial rotation) means there is significant overlap; millions of women possess superior spatial rotation skills compared to the average man.

Therefore, population-level biological data can predict *macro-trends* (e.g., the statistical likelihood that a kindergarten playground will naturally partition into high-intensity physical play among boys and lower-intensity collaborative play among girls) but is entirely useless for determining the aptitude, preferences, or behavior of an *individual* child. Biological sex is a probabilistic indicator, not a deterministic straitjacket.

Conclusion and Syntheses

10-Line Summary of Robust Findings

1. Fetal androgen exposure permanently organizes the neural circuitry of the mammalian brain, establishing physiological sex differences that guide later behavior.
2. The human brain is not strictly "dimorphic"; once adjusted for total volume, biological sex explains only about 1% of the structural variance in neural anatomy.
3. In rodents, perinatal testosterone triggers endocannabinoid signaling, causing microglia to phagocytize astrocytes in the male amygdala, leading to increased neuronal excitation.
4. This localized amygdaloid masculinization directly drives the high intensity of

rough-and-tumble play universally observed in juvenile male mammals.
5. Deprivation of rough-and-tumble play permanently impairs the adult socio-sexual competence and impulse control of male mammals, but has little effect on females.
6. Claims that newborn human females innately prefer faces and males prefer mechanical objects have failed to replicate; both sexes show a baseline preference for faces.
7. Toy preferences are biologically influenced: male monkeys prefer wheeled toys and females prefer plush toys, mimicking human children independent of cultural socialization.
8. Girls with Congenital Adrenal Hyperplasia (CAH) exhibit masculinized play preferences despite parents actively encouraging them to play with female-typical toys.
9. Male advantages in spatial mental rotation and physical risk-taking emerge in childhood and correspond evolutionarily to the male-biased dispersal patterns seen in most mammals.
10. Meta-analyses show parents exercise nearly identical levels of behavioral control (d=0.08) and autonomy support (d=0.03) toward boys and girls in post-industrial societies.

Contested or Open Questions

- **The Dimorphism Debate:** Does the 1% structural variance in human brain tissue identified by Eliot et al. represent trivial noise, or is it concentrated in highly specific, behaviorally potent micro-circuits (like the MeA or SDN-POA) that disproportionately impact socio-sexual behavior?
- **Neonatal Precursors:** What exactly drives the divergence in toy preference by age 1 (e.g., Alexander 2009 eye-tracking data) if large-scale meta-analyses show no significant divergence in social-vs-mechanical visual interest at birth?
- **The "Amber Effect" in Play:** Why does the introduction of specific females into male playgroups abruptly alter the dynamics of rough-and-tumble play, and what are the precise neurological mechanisms of this contextual inhibition?
- **Sensory Modalities of Play:** While social play deprivation impairs adult males, exactly which sensory inputs (tactile friction vs. olfactory/pheromonal exchange) during juvenile wrestling are required to trigger prefrontal cortex maturation?
- **Self-Socialization Mechanisms:** By what specific neural mechanism does prenatal androgen exposure reduce a juvenile female's propensity to imitate same-sex adult models?

5 to 10 Most Important Sources to Read in Full

1. **Eliot, L., et al. (2021).** Dump the "dimorphism": Comprehensive synthesis of human brain studies reveals few male-female differences beyond size. *Neuroscience and Biobehavioral Reviews*.
2. **Pellis, S. M., et al. (2023).** Play fighting and the development of the social brain: The rat's tale. *Neuroscience and Biobehavioral Reviews*.
3. **VanRyzin, J. W., Marquardt, A. E., & McCarthy, M. M. (2019).** Microglial phagocytosis of newborn cells is induced by endocannabinoids and sculpts sex differences in juvenile rat social play. *Neuron*.

4. **Endendijk, J. J., et al. (2016).** Gender-differentiated parenting revisited: Meta-analysis reveals very few differences in parental control of boys and girls. *PLoS ONE*.
5. **Pasterski, V. L., et al. (2005).** Prenatal hormones and postnatal socialization by parents as determinants of male-typical toy play in girls with congenital adrenal hyperplasia. *Child Development*.
6. **Voyer, D., Voyer, S., & Bryden, M. P. (1995).** Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*.
7. **Hassett, J. M., et al. (2008).** Sex differences in rhesus monkey toy preferences parallel those of children. *Hormones and Behavior*.
8. **Byrnes, J. P., Miller, D. C., & Schafer, W. D. (1999).** Gender differences in risk taking: A meta-analysis. *Psychological Bulletin*.
9. **Goy, R. W., & McEwen, B. S. (1980).** *Sexual Differentiation of the Brain*. MIT Press.
10. **Marquardt, A. E., et al. (2023).** Social play experience in juvenile rats is indispensable for appropriate socio-sexual behavior in adulthood in males but not females. *Frontiers in Behavioral Neuroscience*.

Implications for living together

When applying biological and developmental data to the organization of couples, families, and societies, one must vigorously guard against the naturalistic fallacy—the assumption that what is biologically "natural" is therefore morally "good" or socially optimal. Biology provides a baseline of predispositions; it does not dictate our social destiny, nor does it excuse antisocial behavior.

For families, educators, and institutions, the literature carries profound implications for the raising of children, particularly boys. The data decisively shows that rough-and-tumble play is not a behavioral defect, a pathology, or a sign of nascent toxicity. Rather, for juvenile males, intense physical play is a vital neurological nutrient required for the maturation of the prefrontal cortex, impulse control, and adult social competence. Attempting to suppress male-typical physical play in early education environments to align with more sedate, female-typical collaborative norms deprives boys of the friction they require to learn self-regulation. Organizations and schools must carve out unstructured, safe spaces for physical play while teaching children how to negotiate boundaries and recognize role reversals.

Conversely, understanding that toy preferences, spatial abilities, and risk biases have deep evolutionary and hormonal roots should relieve parents of the anxiety that they are "failing" at egalitarian parenting if their daughter gravitates toward dolls or their son toward trucks. Endendijk's meta-analysis proves that parents are already parenting quite equitably regarding control and autonomy; children simply self-socialize according to latent physiological pulls and peer models.

Ultimately, living together successfully requires societies to abandon the expectation of perfectly identical behavioral outcomes between the sexes. Because the variance *within* the sexes is vast, institutions must remain fiercely meritocratic, treating every person as an individual rather than a statistical mean. However, at the macro-level, policymakers and families must accommodate the reality of overlapping but distinct biological trajectories, designing social environments that honor the natural neurodevelopmental needs of both boys and girls.

Allowing both sexes the freedom to express their biological predispositions, while socializing them toward mutual respect and cooperation, remains the most evidence-based foundation for human flourishing.

Works cited

1. Sexual Differentiation of the Brain in Man and Animals - PMC - NIH, https://pmc.ncbi.nlm.nih.gov/articles/PMC5320421/
2. Effects of prenatal androgens on rhesus monkeys: A model system, https://pmc.ncbi.nlm.nih.gov/articles/PMC3146061/
3. Hormonal influences on sexually differentiated behavior in, https://www.psych.ualberta.ca/~phurd/papers/Wallen_05.pdf
4. Sexual Differentiation of the Rodent Brain: Dogma and Beyond, https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2012.00026/full
5. (PDF) Sexual Differentiation of the Brain: A Fresh Look at Mode, https://www.researchgate.net/publication/312007382_Sexual_Differentiation_of_the_Brain_A_Fresh_Look_at_Mode_Mechanisms_and_Meaning
6. Gonadal hormones and behavior of normal and ... - PubMed, https://pubmed.ncbi.nlm.nih.gov/4631621/
7. (PDF) Organizational Effects of Gonadal Hormones on Human, https://www.researchgate.net/publication/374055009_Organizational_Effects_of_Gonadal_Hormones_on_Human_Sexual_Orientation
8. The transcriptome of playfulness is sex biased in the juvenile rat, https://www.researchgate.net/publication/392423111_The_transcriptome_of_playfulness_is_sex_biased_in_the_juvenile_rat_medial_amygdala_A_role_for_inhibitory_neurons
9. Microglial Phagocytosis of Newborn Cells Is Induced by, https://www.researchgate.net/publication/331427583_Microglial_Phagocytosis_of_Newborn_Cells_Is_Induced_by_Endocannabinoids_and_Sculpts_Sex_Differences_in_Juvenile_Rat_Social_Play
10. Microglial Phagocytosis of Newborn Cells Is Induced by ... - PubMed, https://pubmed.ncbi.nlm.nih.gov/30827729/
11. Sampling recent research on male-female brains - socbres, https://socbres.com/sampling-recent-science-on-girl-boy-brains.htm
12. Comprehensive synthesis of human brain studies reveals few male, https://pubmed.ncbi.nlm.nih.gov/33621637/
13. Gender Differences in Rough and Tumble Play Behaviors, https://www.researchgate.net/publication/301746443_Gender_Differences_in_Rough_and_Tumble_Play_Behaviors
14. Assessing Rough-and-tumble Play Behavior in Juvenile Rats, https://pubmed.ncbi.nlm.nih.gov/33654714/
15. Sex differences in play fighting revisited: traditional and ... - PubMed, https://pubmed.ncbi.nlm.nih.gov/11910788/
16. Gender Differences in Rough and Tumble Play Behaviors,

https://digitalcommons.cwu.edu/cgi/viewcontent.cgi?article=1178&context=ijurca
17. Gender Differences in Rough and Tumble Play Behaviors, https://digitalcommons.cwu.edu/ijurca/vol8/iss1/4/
18. Play fighting and the development of the social brain: The rat's tale, https://pubmed.ncbi.nlm.nih.gov/36621585/
19. The Function of Play in the Development of the Social Brain, https://www.museumofplay.org/app/uploads/2022/01/2-3-article-function-play-development-social-brain.pdf
20. The Function of Play in the Development of the Social Brain - ERIC, https://eric.ed.gov/?id=EJ1069225
21. Social play experience in juvenile rats is indispensable for ... - PubMed, https://pubmed.ncbi.nlm.nih.gov/36755666/
22. Social play experience in juvenile rats is indispensable for ... - PMC, https://pmc.ncbi.nlm.nih.gov/articles/PMC9899815/
23. Sex differences in human neonatal social perception, https://www.math.kth.se/matstat/gru/5b1501/F/sex.pdf
24. [PDF] Sex differences in human neonatal social perception, https://www.semanticscholar.org/paper/Sex-differences-in-human-neonatal-social-perception-Connellan-Baron-Cohen/50c7f3fb0b144fb648fb4238d01d2837c57ce36b
25. Sex Differences in Human Neonatal Social Perception - ResearchGate, https://www.researchgate.net/publication/222673203_Sex_Differences_in_Human_Neonatal_Social_Perception
26. Sex-related preferences for real and doll faces versus real and toy, https://www.researchgate.net/publication/255733999_Sex-related_preferences_for_real_and_doll_faces_versus_real_and_toy_objects_in_young_infants_and_adults
27. Sex differences in infants' visual interest in toys - PubMed, https://pubmed.ncbi.nlm.nih.gov/19016318/
28. Sex differences in response to children's toys in nonhuman primates, https://cognitionandculture.net/wp-content/uploads/1-s2.0-S1090513802001071-main.pdf
29. Sex differences in rhesus monkey toy preferences parallel ... - Free, http://humanbehaviors.free.fr/References%20-%20Articles/Sex%20differences%20in%20rhesus%20monkey%20toy%20preferences%20parallel%20those%20of%20children.pdf
30. Hassett et al. (monkey toy preferences) - Simply Psychology, https://www.simplypsychology.org/hassett-et-al-monkey-toy-preferences.html
31. Hassett et al.'s Monkey Toy Preferences Study | PDF | Gender - Scribd, https://www.scribd.com/presentation/715646092/2-Hassett-et-al
32. Sex differences in rhesus monkey toy preferences parallel ... - PubMed, https://pubmed.ncbi.nlm.nih.gov/18452921/
33. Prenatal androgen exposure and children's gender-typed behavior, https://pmc.ncbi.nlm.nih.gov/articles/PMC7856278/
34. Prenatal hormones and postnatal socialization by parents ... - PubMed,

https://pubmed.ncbi.nlm.nih.gov/15693771/
35. Prenatal Hormones and Postnatal Socialization by Parents as, https://academic.oup.com/chidev/article-abstract/76/1/264/8275352
36. Sex Differences in Wild Chimpanzee Behavior Emerge during Infancy, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0099099
37. sex differences in wild infant chimpanzee social interactions - PubMed, https://pubmed.ncbi.nlm.nih.gov/24489384/
38. Publications | primate - Elizabeth Lonsdorf, https://www.elizabeth-lonsdorf.com/publications
39. Prenatal androgen exposure alters girls' responses to ... - PubMed, https://pubmed.ncbi.nlm.nih.gov/26833843/
40. Gender Differences in Risk Taking: A Meta-Analysis - ResearchGate, https://www.researchgate.net/profile/James-Byrnes-2/publication/271767506_Gender_differences_in_risk_taking_A_meta-analysis/links/56e9904208ae95bddc29f1a6/Gender-differences-in-risk-taking-A-meta-analysis.pdf
41. Gender Differences in Risk Taking: A Meta-Analysis - ResearchGate, https://www.researchgate.net/publication/232541633_Gender_Differences_in_Risk_Taking_A_Meta-Analysis
42. Gender differences in risk taking: A meta-analysis - ResearchGate, https://www.researchgate.net/publication/271767506_Gender_differences_in_risk_taking_A_meta-analysis
43. The development of gender differences in spatial reasoning - PubMed, https://pubmed.ncbi.nlm.nih.gov/30973235/
44. Magnitude of Sex Differences in Spatial Abilities: A Meta-Analysis, https://www.researchgate.net/publication/15473878_Magnitude_of_Sex_Differences_in_Spatial_Abilities_A_Meta-Analysis_and_Consideration_of_Critical_Variables
45. The Development of Gender Differences in Spatial Reasoning, https://www.researchgate.net/publication/330811027_The_Development_of_Gender_Differences_in_Spatial_Reasoning_A_Meta-Analytic_Review
46. Spatial Ability and Prenatal Androgens: Meta-analyses of CAH and, https://pmc.ncbi.nlm.nih.gov/articles/PMC2883918/
47. Contributions of gonadal hormones in the sex-specific organization, https://pmc.ncbi.nlm.nih.gov/articles/PMC9980802/
48. Sex-biased dispersal patterns depend on the spatial scale in ... - PMC, https://pmc.ncbi.nlm.nih.gov/articles/PMC2817192/
49. Advances in our understanding of mammalian sex-biased dispersal, https://pubmed.ncbi.nlm.nih.gov/17402974/
50. Gender-Differentiated Parenting Revisited: Meta-Analysis ... - PubMed, https://pubmed.ncbi.nlm.nih.gov/27416099/
51. Gender-Differentiated Parenting Revisited: Meta-Analysis Reveals, https://www.researchgate.net/publication/305339257_Gender-Differentiated_Parenting_Revisited_Meta-Analysis_Reveals_Very_Few_Differences_in_Parental_Control_of_Boys_and_Girls
52. Gender-Differentiated Parenting Revisited: Meta-Analysis Reveals, https://pmc.ncbi.nlm.nih.gov/articles/PMC4945059/