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RESEARCH

Sex Biases in Patterns of Parental Investment

F. Sid Dougan[1] · **William Costello**[1] · **David M. Buss**[1]

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Abstract

Most research on human parental investment has focused on overall parental effort or resource allocation, overlooking the fact that human investment spans a broad suite of material, instructional, and social forms of investment. This array of investment enables examination of how evolutionary processes have elaborated parental care into distinct domains. Where daughters and sons historically faced different recurrent adaptive problems, selection should have favoured biases in parental investment that cultivate in each offspring the competencies relevant to its sex-specific challenges (e.g., navigating greater reproductive costs for daughters; navigating contest competition for sons). Likewise, mothers and fathers should differ in parental investment domains where their own evolutionary and life histories afforded greater sex-specific expertise. To test these hypotheses, we used linear mixed-effect models to analyse 105 adults' (49.5% female) ratings of parental investment received across 73 behaviours organised into 13 domains. Results were largely consistent with predictions. Daughters received more parental investment in mating and relationship guidance, protection, and material support. Sons received greater parental investment in athletic training, permissiveness regarding sexual behaviour, and competitive encouragement. Mothers invested more than fathers in direct care, bonding, social and moral guidance, and discipline. Fathers invested more in athletics, and mechanical and practical skills. Domains linked to adaptive challenges common to both sexes (e.g., direct care) showed no offspring-sex differences in parental investment. The patterns accord with the evolutionary hypothesis that parental investment maps onto sex-differentiated adaptive problems. Discussion explores hypotheses about the interactions between socialisation practices of parents and sex-linked predispositions in offspring.

Keywords Parental Investment · Sex Differences · Biparental Care · Daughter-Son Differences · Maternal Investment · Paternal Investment

Extended author information available on the last page of the article

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Introduction

Inclusive fitness theory posits that individuals can increase their evolutionary fitness not only through their own direct reproduction, but also by enhancing the survival and reproductive prospects of others who carry copies of their genes (Hamilton, 1964). Engaging in parental care follows from this logic. Because offspring inherit half their genes from each parent, over evolutionary time parents gain inclusive fitness returns by aiding offspring survival and future reproductive prospects.

Despite the potential fitness benefits of parental investment, such investment is far from universal. Across the animal kingdom, parental care occurs in only ~ 10–20% of species (Royle et al., 2012). Biparental care, where both sexes contribute substantially to offspring development, is rarer still, occurring in only ~ 1% of animal species overall (Royle et al., 2012), and only ~ 3–5% of mammalian species (Kleiman, 1977; Lukas & Clutton-Brock, 2013).

Against this broader backdrop of rarity, humans stand out as a striking exception in at least three respects with regard to parental investment: (1) the sheer magnitude and duration of investment, often extending well into offspring's teens and beyond, (2) substantial paternal as well as maternal investment, and (3) the diversity of forms that parental investment takes.

Consider our closest relative, the chimpanzee. Although chimpanzee mothers continue to associate with offspring well beyond weaning, direct provisioning largely ends around ages 4–6 (Samuni et al., 2020). Paternal investment among chimpanzees is typically zero (Lehmann et al., 2006). Given that wild chimpanzees who survive to maturity live an average of ~ 30 years (Hill et al., 2001), maternal provisioning occupies about one sixth to one fifth of the lifespan. In human hunter-gather populations, by contrast, roughly one quarter to one third of life is spent under active parental investment (Hill et al., 2001; Kaplan et al., 2000).

The evolutionary origins of humans' unusually prolonged and biparental care are hypothesised to lie in co-evolving life-history and mating-system shifts (Geary, 2015; Geary & Flinn, 2001). In most species, high paternity uncertainty constrains substantial male parental investment, as males risk investing in unrelated offspring. In humans, concealed ovulation and extended female sexuality (i.e. sexual receptivity and proceptivity beyond the fertile window) obscure the timing of fertilisation. Consequently, males cannot reliably concentrate mate guarding effort around clearly identifiable fertile phases. It is thought, therefore, that this favoured prolonged male-female association and long-term, high-commitment mating bonds. These more stable bonds are proposed to have increased paternity certainty, thereby making sustained paternal investment evolutionarily favourable (Geary, 2015; Geary & Flinn, 2001). Such shifts are suggested to have co-evolved with prolonged juvenile dependency and increasing social complexity, creating conditions under which paternal investment could yield reliable fitness returns (Geary, 2015; Geary & Flinn, 2001).

Despite the central role of parental investment in human evolution, how it is organised across the diverse domains in which it operates remains largely unexplored. Unlike other species, in humans, the combination of social complexity and prolonged

juvenile dependency is accompanied by an exceptionally varied range of parental investments beyond provisioning and protection that includes the teaching of skills, socialisation, moral guidance, and the transmission of cultural knowledge (Caldwell et al., 2018; Castro & Toro, 2014; Fogarty et al., 2011; Gärdenfors & Högberg, 2017; Sterelny, 2023). Such breadth demands a more fine-grained account of how parental effort is structured across functionally distinct domains—an account essential to any comprehensive evolutionary theory of human parenting.

Within an evolutionary framework, parental investment is defined as the parental expenditure of time, energy, and resources, that benefit offspring at a cost to the parent's ability to invest in other offspring (Trivers, 1972). In humans, parental investment encompasses direct and indirect forms of care that often extend well into adolescence and even adulthood. Previous research has shown that human parental investment varies in response to ecological and reproductive contexts, including parental condition, offspring condition, offspring sex, offspring number, resource availability, and local social competition (e.g., de Baca & Ellis, 2017; Beaulieu & Bugental, 2008; Browne et al., 2018; Chang et al., 2017; Low, 1989; Schacht et al., 2018). Cross-cultural analyses, for example, show that parental socialisation of sons and daughters covaries with local mating systems, with greater encouragement of male-male contest competition in more polygynous societies, and stronger emphasis on female restraint and domestic responsibility (Low, 1989). This pattern reflects evolutionary accounts in which parental investment is flexibly adjusted and allocated toward domains expected to yield greater reproductive payoffs. Such context-dependent adjustments are hypothesised to have evolved because, on average, they enhanced offspring reproductive success (de Baca et al., 2012; de Baca & Ellis, 2017; Möller et al., 2013).

Despite substantial research on the ecological and life-history determinants of parental investment, little research has attempted to establish how such investment is directed toward different domains (but see Shepard, 1980). Many studies examine parental investment in terms of overall time spent with offspring, or financial investment (often in education), rather than the specific forms that investment takes (e.g., Craig, 2006; Gauthier et al., 2004; Hastings & Schneider, 2021; Hedges et al., 2016; Kornrich, 2016; Schneider et al., 2018). Of the studies that have examined specific domains of parental investment, however, most have focused narrowly on single domains, such as education (e.g., Borgstede & Scheunpflug, 2023; Hedges et al., 2016; Hopcroft & Martin, 2014), or relationship guidance (e.g., Kapungu et al., 2010; Kauffman et al., 2013; Kuhle et al., 2015), without assessing how various forms of investment compare to one another.

This leaves open at least three fundamental questions. (1) How do parents distribute their effort across the full suite of potential investment domains? (2) Do mothers and fathers differ in the specific domains in which they invest? (3) Do parents allocate investment across domains differently for daughters and sons?

To our knowledge, no prior research has systematically compared maternal and paternal investment across multiple functionally distinct domains. The present study addresses this gap by examining how mothers and fathers allocate effort across a comprehensive set of parental-investment domains. By analysing investment sepa-

rately across multiple domains, this work provides the first multidimensional test of whether parental investment is differentiated by both sex of offspring and sex of parent, and whether any such differences are broad or relatively confined to specific, theoretically predictable domains. We now outline the rationale for the hypothesised patterns and the specific predictions derived from this framework.

The Present Study

Throughout human evolutionary history, males and females faced many of the same adaptive challenges, but each sex also faced its own distinct set of adaptive problems (Benenson, 2014; Benenson & Abadzi, 2020; Buss, 1995; Hrdy, 2009; Kramer, 2023; Marlowe, 2007; Micheletti et al., 2018; Puts, 2010; Puts et al., 2016; Sear & Mace, 2008; Trivers, 1972; Van Vugt, 2009; Venkataraman et al., 2024). Where such challenges were shared among both sexes, similar adaptive solutions are expected to have evolved in both. But where adaptive challenges were sex-differentiated, selection should have favoured the evolution of somewhat different motivations, skills, and behavioural specialisations in each sex.

Because parental fitness depends on the success of both sons and daughters, selection should have favoured parental investment strategies that promote in each offspring the abilities most relevant to its sex-specific adaptive challenges. Accordingly, parents should allocate investment differently in domains linked with sex-differentiated problems, whereas they should allocate investment similarly in domains linked with adaptive problems common to both sexes. Moreover, because mothers and fathers differ in the adaptive challenges they typically encounter across their own lifetimes, each is expected to invest more heavily in domains where their experiences and skills afford a comparative advantage.

Women bear higher obligatory reproductive costs than men (Trivers, 1972), and thus greater fitness risks from poor mate choice. Parents, but mothers in particular, should therefore emphasise mating and relationship guidance more for daughters than for sons. By contrast, because male reproductive success has depended more on intrasexual competition and coalitionary aggression (Puts et al., 2016), parents, but fathers in particular, should emphasise the development of physical strength and competitiveness in sons. Such domain- and sex-specific investments would prepare offspring for the adaptive challenges typical of their sex.

In addition to enhancing in offspring the skills required to solve sex-specific adaptive problems, many sex-biased patterns of parental investment likely serve an additional function: enhancing offspring mate value. Investing in athletics and physical training in sons, for example, may increase their mate value because women across cultures have mate preferences for strong, athletic, muscular men (Butovskaya et al., 2024; Dixson et al., 2003; Frederick & Haselton, 2007; Garza et al., 2021; Schulte-Hostedde et al., 2008; Sell et al., 2017), and such men tend to have greater mating success (Hönekopp et al., 2007; Smith & Hagen, 2025). Such investment would therefore yield inclusive fitness benefits through two partially separate pathways, and consequently may be subject to strong and consistent selection.

Hypotheses

Based on the described evolutionary framework, we propose two hypotheses:

- **H1**. In domains corresponding to adaptive problems that historically differed for daughters and sons, selection should have favoured parental investment biases that cultivate in each offspring the competencies relevant to its sex-specific challenges.
- **H2**. Mothers and fathers should allocate investment differently in domains where ancestral selection pressures produced sex-differentiated expertise, with each parent investing relatively more in domains aligned with their own sex-specific evolutionary specialisations and life-history experiences.

Specific predictions derived from these hypotheses, and a brief evolutionary rationale for each, are detailed below.

Predictions

Overall Parental Investment (Averaged Across Domains)

- **P1**. Averaged across all domains, mothers will provide more parental investment than fathers.

    ◦ Rationale: Because mothers bear the higher minimum obligate investment, parental investment theory leads to the prediction of stronger selection for higher maternal contribution on average (Trivers, 1972).

Daughters vs. Sons (Averaged Across Mothers and Fathers)

- **P2**. Daughters will receive more parental investment than sons in the following domains: mating and relationship guidance, social and moral guidance.

    ◦ *Rationale*: Higher female reproductive costs and greater fitness risks from poor mate choice should select for stronger parental influence on daughters' social and mating decisions. (Perilloux et al., 2008; Trivers, 1972).

- **P3**. Sons will receive more parental investment than daughters in the following domains: sexual permissiveness, athletics and physical training, mechanical and practical skills, competitive encouragement.

    ◦ *Rationale*: Lower reproductive costs and greater potential gains from multiple mating should have selected for greater parental permissiveness toward sons' sexual behaviour. Male-specific demands in warfare, big-game hunting, and status-driven competition should also have selected for parental emphasis on developing sons' physical, competitive, and practical competencies.

- **P4**. Daughters and sons will receive comparable parental investment in the following domains: direct care and domestic support, bonding and emotional support, education and career support, protection, discipline and regulation, wisdom and life guidance, material provisioning.

    ◦ *Rationale*: These domains address adaptive challenges shared by both sexes, so parents are expected to invest in daughters and sons at similar levels.

Mothers vs. Fathers (Averaged Across Daughters and Sons)

- **P5**. Mothers will provide more parental investment than fathers in the following domains: direct care and domestic support, discipline and regulation, mating and relationship guidance, social and moral guidance, bonding and emotional support.

    ◦ *Rationale*: Over ancestral time, mothers' higher obligate investment and continuous involvement in offspring development should have selected for stronger maternal motivation and expertise in nurturing, socialisation, and interpersonal guidance.

- **P6**. Fathers will provide more parental investment than mothers in the following domains: athletics and physical training, mechanical and practical skills, competitive encouragement.

    ◦ *Rationale*: Over ancestral time, the sex-specific demands males faced in warfare, hunting, and status competition would have produced greater male expertise in physically demanding, tool-based, and competitive domains. Because fathers were better equipped to instil these skills in offspring, natural selection should have favoured stronger paternal motivation to invest in these areas.

- **P7**. Mothers and fathers will provide equivalent parental investment in the following domains: education and career support, protection, wisdom and life guidance, material provisioning, sexual permissiveness.

    ◦ *Rationale*: Over ancestral time, mothers and fathers did not differ systematically in the skills or experience relevant to education and career support, protection, wisdom and life guidance, or material provisioning. Natural selection therefore should not have favoured specialised maternal or paternal investment in these areas. Though sexual permissiveness is predicted to vary by offspring sex (P3), the amount provided should not differ between mothers and fathers, because both share convergent fitness interests in favouring greater sexual permissiveness in sons and greater sexual restriction in daughters.

Parent × Offspring Sex Interactions

- **P8**. Mothers will show a larger bias toward daughters over sons than fathers will in the following domains: mating and relationship guidance, social and moral guidance.

    ◦ *Rationale*: Because daughters face higher reproductive costs and greater fitness risks from poor social and mating decisions, and because mothers' higher obligate investment historically selected for stronger expertise in socialisation and interpersonal guidance, natural selection should have favoured larger mother-daughter investment biases in these domains.

- **P9**. Fathers will show a larger bias toward sons over daughters than mothers will in the following domains: athletics and physical training, mechanical and practical skills, competitive encouragement.

    ◦ *Rationale*: Because sons historically faced greater demands in physical competition, tool-based tasks, and status acquisition, and because males' ancestral roles selected for greater paternal expertise in these domains, natural selection should have favoured larger father-son investment biases in these areas.

Methods

To test these predictions and fill the empirical gap regarding domain-specific parental investment, we analysed retrospective reports from adult participants describing the parental investment they received from their mothers and fathers across a range of domains. This design enabled systematic tests of main effects of parent and offspring sex, as well as their interaction, on patterns of parental investment across domains.

We analysed data from a longitudinal study of newlywed heterosexual couples initially recruited in 1989 through public records of marriage licenses issued in Washtenaw County, Michigan, USA (see Buss, 1989, 1991). Couples had been married less than one year at initial recruitment and were contacted by mail and invited to participate. The present analyses use parental investment data collected at Time-2, when participants were in their third year of marriage ($N = 105$ adults; 52 couples, reduced due to attrition, with one missing spouse). At this wave, participants completed a 105-item questionnaire assessing a broad range of parental behaviours, rating the extent to which each behaviour was performed by their biological mother and father while they were growing up, on a Likert scale ranging from 0 (not at all) to 7 (a great deal).

Participant age ranged from 19 to 36 (mean = 26). Most participants (92.4%) identified as white, 3.8% identified as black/brown, and 3.8% identified as other. More than half the participants reported being raised in a middle socio-economic bracket

(53.3%), followed by lower-middle (24.8%) and upper-middle (21.0%), with one missing response. Most participants reported being raised in suburban areas (56.2%) of the USA, followed by rural (20.0%) and urban (18.1%) areas, with 3.8% raised outside the USA; two participants did not provide this information.

The development of the domain structure proceeded in two stages. First, all 105 items were reviewed by the lead author and provisionally sorted into conceptually related clusters based on their underlying functional content. These provisional classifications were then reviewed and discussed with the co-authors, and refined through iterative discussion. This process yielded 13 candidate domains representing distinct forms of parental investment. Second, the full set of items was re-evaluated against these domains using criteria of conceptual clarity and domain specificity. Items were removed if they were judged to be overly vague in meaning or to overlap conceptu-

Table 1 Parental investment domains with example items and internal consistency coefficients (Cronbach's α). α coefficients were computed collapsing across mother and father reports and are not reported for single-item domains

Domain	Example Items	α
Mating & Relationship Guidance	Talked to me about marriage, love. Taught me about sex.	.88
Athletics & Physical Training	Taught me athletics. Encouraged me to get involved in athletics.	.85
Mechanical & Practical Skills	Taught me to build things. Taught me to drive.	.68
Social & Moral Guidance	Helped me learn how to communicate. Taught me how to be honest.	.95
Competitive Encouragement	Motivated me to compete.	—
Sexual Permissiveness	Was permissive about sex.	—
Direct care & Domestic Support	Took care of me when I was sick. Fed me.	.77
Bonding & Emotional Support	Gave me encouragement when I was down. Joked with me.	.95
Education & Career support	Helped me on my schoolwork. Supplied info about schools and jobs.	.93
Protection	Provided protection.	—
Discipline & Regulation	Provided discipline. Punished me when I deserved it.	.81
Wisdom & Life Guidance	Shared their own experiences. Gave me the best advice and guidance.	.89
Material Provisioning	Gave me money when I needed it. Bought me presents.	.87

ally with multiple domains, thereby limiting their ability to index a distinct form of investment. Decisions at this stage were likewise discussed and agreed upon among the authors. This process resulted in the removal of 32 items. The final set comprised 73 items organised into 13 coherent domains, which served as the basis for all subsequent analyses (see Table 1). A full list of items and their domain assignments is available in the Supplementary Materials.

Statistical Analysis

A linear mixed-effects model was used to predict investment ratings from offspring sex, parent, and investment domain, including all interactions. Random intercepts were specified for individuals and for couples to account for the non-independence of observations within dyads:

$$\text{Response} = \text{Sex} \times \text{Parent} \times \text{Domain} + (1 \mid \text{ID}) + (1 \mid \text{CoupleID})$$

Models were estimated in R using the packages *lme4* (Bates et al., 2015), *lmerTest* (Kuznetsova et al., 2017), and *emmeans* (Lenth, 2023). Sum-to-zero contrasts were applied to permit Type-III tests of main effects and interactions.

Type-III ANOVA tables were used to evaluate omnibus effects for sex, parent, and investment domain. To interpret these effects, estimated marginal means were computed for the 2 × 2 Parent × Sex combinations within each investment domain. Planned contrasts compared (a) mothers versus fathers separately for sons and for daughters, and (b) the difference-of-differences representing the Sex × Parent interaction within each domain. For each comparison, *emmeans* provided estimated differences, standard errors, 95% confidence intervals, and two-tailed *p*-values.

Results

Model Fit and Explained Variance

A marginal and conditional R^2 analysis indicated that the model explained 33.1% of the variance in parental investment through fixed effects, and 58.6% of the total variance when random effects for participant and couple membership were included. This suggests that approximately one-third of the predictable variation in parental investment reflects systematic effects of offspring sex, parent sex, and domain, with the remainder attributable to stable individual differences and modest within-couple similarity.

Main Effects and Interactions Across Domains

Because the study included many parental-investment domains and multiple contrasts for each, we present the full set of results in Table 2 for clarity and ease of interpretation.

Table 2 Results table summarising observed patterns across parental investment domains. Daughter-son and mother-father contrasts are shown for every domain. Parent × offspring sex interaction effects are presented only for domains in which a priori predictions were specified. Interactions in all other domains were tested but were not statistically significant and are therefore not displayed in the table "=" denotes no significant difference; ">" denotes the direction of significant difference. Cohen's d values were computed separately using domain-specific residual standard deviations (see Supplementary Materials). * = $p \leq .05$; ** = $p \leq .01$; *** = $p \leq .001$

Domain	Observed Pattern	Result	Cohen's *d*	Prediction
All Domains Combined	Daughters=Sons (*averaged across parents*)	$t=0.43, p<0.666$	0.04	—
	Mothers>Fathers (*averaged across offspring sex*)	$t=5.26, p<0.001$***	0.20	Supported
	Mothers>Fathers (*within daughters only*)	$t=6.60, p<0.001$***	0.36	—
	Mothers=Fathers (*within sons only*)	*$t=0.91, p=0.363$*	0.05	—
	Mother × Daughter Interaction	*$t=-3.96, p<0.001$***	—	—
Mating & Relationship Guidance	Daughters>Sons	$t=2.74, p=0.007$**	0.68	Supported
	Mothers>Fathers	$t=5.71, p<0.001$***	1.13	Supported
	Mother × Daughter Interaction	$t=-4.19, p<0.001$***	—	Supported
Athletics & Physical Training	Sons>Daughters	$t=-3.69, p<0.001$***	−0.84	Supported
	Fathers>Mothers	$t=-3.19, p=0.001$***	−0.56	Supported
	Father × Son Interaction	$t=-2.12, p=0.035$*	—	Supported
Mechanical & Practical Skills	Daughters=Sons	$t=-1.10, p=0.272$	−0.18	Not Supported
	Fathers>Mothers	$t=-5.93, p<0.001$***	−0.76	Supported
	Father × Son Interaction	$t=-2.45, p=0.015$*	—	Supported
Social & Moral Guidance	Daughters=Sons	$t=1.84, p=0.066$	0.49	Not Supported
	Mothers>Fathers	*$t=3.28, p<0.001$***	0.67	Supported
	No Mother × Daughter Interaction	*$t=-1.39, p=0.165$*	—	Not Supported
Competitive Encouragement	Sons>Daughters	$t=-2.82, p=0.005$**	−0.57	Supported
	Mothers=Fathers	$t=-1.50, p=0.135$	−0.23	Not Supported
	No Father × Son Interaction	*$t=-0.56, p=0.573$*	—	Not Supported
Sexual Permissiveness	Sons>Daughters	$t=-3.45, p<0.001$***	−1.06	Supported
	Mothers=Fathers	$t=-0.47, p=0.641$	−0.13	Supported
Direct care & Domestic Support	Daughters=Sons	$t=1.02, p=0.310$	0.19	Supported
	Mothers>Fathers	$t=13.46, p<0.001$***	2.00	Supported
Bonding & Emotional Support	Daughters=Sons	$t=1.68, p=0.095$	0.40	Supported
	Mothers>Fathers	$t=5.00, p<0.001$***	0.91	Supported
Education & Career support	Daughters=Sons	$t=1.77, p=0.078$	0.53	Supported
	Mothers=Fathers	$t=0.91, p=0.361$	0.21	Supported
Protection	Daughters>Sons	$t=2.24, p=0.026$*	0.47	Not Supported
	Mothers=Fathers	$t=1.15, p=0.250$	0.17	Supported
Discipline & Regulation	Daughters=Sons	$t=0.25, p=0.806$	0.08	Supported
	Mothers>Fathers	$t=2.68, p=0.007$**	0.47	Supported

Table 2 (continued)

Domain	Observed Pattern	Result	Cohen's *d*	Prediction
Wisdom & Life Guidance	Daughters = Sons	$t=1.61, p=0.109$	0.32	Supported
	Mothers > Fathers	$t=3.38, p<0.001$***	0.52	Not Supported
Material Provisioning	Daughters > Sons	$t=2.06, p=0.041$*	0.53	Not Supported
	Mothers = Fathers	$t=1.07, p=0.287$	0.20	Supported

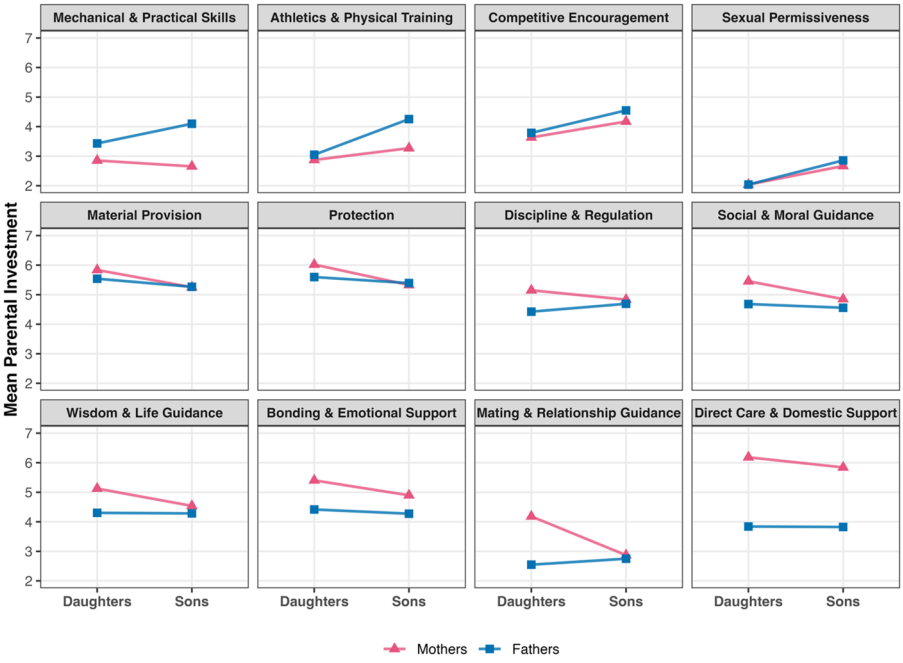

Fig. 1 Mean parental investment by offspring sex and parent across 12 investment domains. Lines and symbols represent mothers (pink triangles) and fathers (blue squares), with symbols showing the mean level of reported investment for daughters and sons. The education and career support domain was excluded because it showed no significant effects in any analysis (offspring sex, parent, or interaction) and its removal allowed an even 4 × 3 facet layout

To facilitate interpretation of the patterns summarised in Table 2; Fig. 1 illustrates mean levels of parental investment across domains by offspring sex and parent. Figure 2 shows the corresponding Cohen's *d* effect sizes for daughter-son contrasts within each parent across domains. Figure 3 shows Cohen's *d* effect sizes for mother-father contrasts within each offspring sex across domains.

Discussion

We examined whether parental investment varies systematically by offspring sex and parent sex across distinct investment domains, including those that map onto historically sex-differentiated adaptive challenges. Drawing on an evolutionary framework

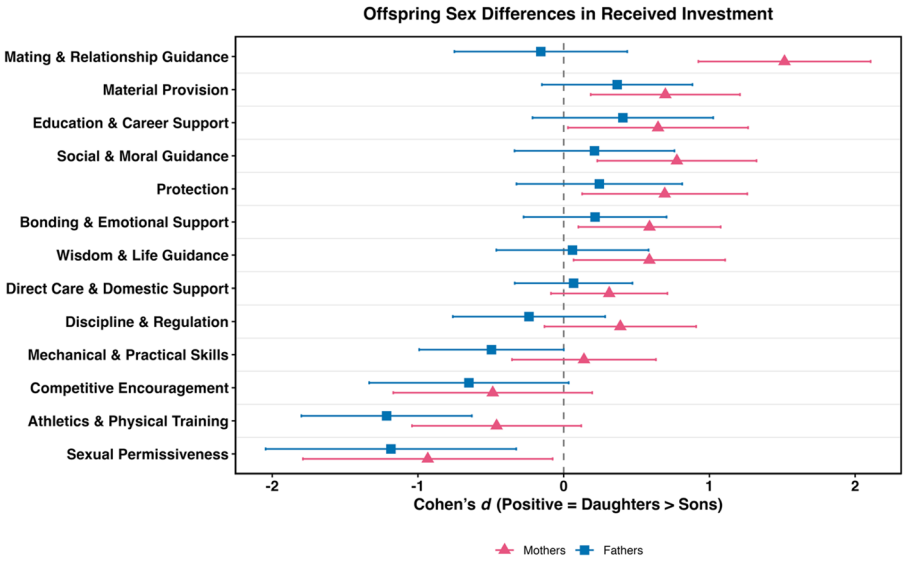

Fig. 2 Coefficient (dot-and-whisker) plot showing Cohen's d effect sizes for daughter-son differences within each parent across parental investment domains. Each point represents the daughter-son contrast for that parent only (Daughter − Son), plotted separately for mothers (pink triangles) and fathers (blue squares). The dashed vertical line at zero denotes parity between daughters and sons. Values to the left of zero indicate greater investment received by sons, and values to the right indicate greater investment received by daughters. Error bars show 95% confidence intervals

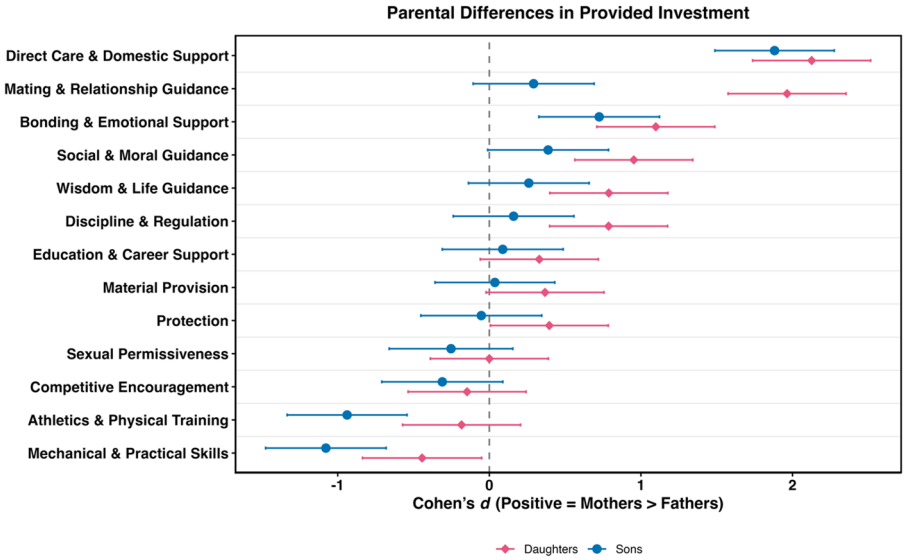

Fig. 3 Coefficient (dot-and-whisker) plot showing Cohen's d effect sizes for mother-father differences within each offspring sex across parental investment domains. Each point represents the mother-father contrast for that offspring sex only (Mother − Father), plotted separately for daughters (pink diamonds) and sons (blue circles). The dashed vertical line at zero denotes parity between mothers and fathers. Values to the left of zero indicate greater investment from fathers, and values to the right indicate greater investment from mothers. Error bars show 95% confidence intervals

in which parental investment strategies are hypothesised to promote the development of abilities and priorities most relevant to sex-specific adaptive challenges, we tested a set of domain-specific predictions rather than relying on a single global measure of investment. Overall, the findings support the view that parental investment is structured in a domain-specific manner, with sex-biased patterns evident in particular domains rather than as a general bias in parental investment. Below we discuss these patterns, focusing on how variation across domains can be understood within an evolutionary framework. We then turn to interpretive issues, discussing the causal relationship between sex-differentiated behaviour and parental socialisation, and how an evolutionary perspective helps reconcile evolutionary and sociocultural accounts often treated as competing explanations.

Overall Parental Investment (Averaged Across Domains)

As predicted, mothers provided more overall parental investment than fathers, but this difference was especially pronounced for daughters, who received more maternal than paternal investment, whereas sons showed no such difference.

This is largely consistent with previous research showing that, overall, mothers tend to take on more childrearing responsibilities, and invest more time and resources into childcare than fathers (Craig, 2006; Geary, 2000; Parke, 2002; Sear & Mace, 2008). Likewise, a cross-cultural review of 45 populations revealed that maternal death consistently had a large, detrimental impact on child survival, whereas paternal death often had less effect, underscoring mothers' primary role as offspring caregivers (Sear & Mace, 2008).

From an evolutionary perspective this maternal predominance aligns with Trivers' (1972) parental investment theory, which emphasises that females are the higher-investing sex because of their greater minimum obligatory reproductive costs (e.g. gestation, childbirth, and lactation). These obligatory investments mean that the remaining investment required to rear offspring to independence is typically lower than the investment required to abandon them and rear replacements, making continued investment more likely to yield higher expected future fitness returns for mothers. A further asymmetry favouring higher maternal investment is maternity certainty: unlike fathers, mothers have guaranteed genetic relatedness to both daughters and sons, which strengthens the expected returns to their investment.

The overall mother-daughter bias we observed may be partly explained by the downstream inclusive fitness consequences of maternity certainty. Mothers are certain not only of their relatedness to their own children but also of their relatedness to future grandchildren produced by daughters. Grandchildren through sons, however, remain subject to paternity uncertainty. This asymmetry could, in some contexts, create stronger expected inclusive fitness returns from investing in daughters, and is thought to explain matrilineal biases in grandparental investment (Bishop et al., 2009; Euler & Weitzel, 1996). The extent to which this mechanism shapes mother-daughter biases in investment cannot be established from our data alone, and any such effects are likely to be ecologically contingent. It nevertheless offers a plausible evolutionary route by which a mother-daughter bias in overall investment could

emerge, even though domain-level patterns are expected to track the distinct adaptive challenges faced by sons and daughters.

Mating and Relationship Guidance, Sexual Permissiveness

As predicted, daughters received significantly more mating and relationship guidance than sons. Mothers provided more relationship guidance than fathers. And mothers showed a stronger bias toward daughters than toward sons in provided mating and relationship guidance. Additionally, both mothers and fathers imposed greater sexual restrictiveness on daughters than on sons. These findings are consistent with previous research. Mothers tend to communicate more about sex-related topics than fathers, daughters receive more such information from parents than sons, and sex-related messages relayed to daughters are typically protective and restrictive, whereas those relayed to sons often endorse sexual exploration (Kapungu et al., 2010; Kauffman et al., 2013; Kuhle et al., 2015; Low, 1989; Morgan et al., 2010; Widman et al., 2016; Wilson et al., 2010).

As well as aligning with our hypotheses, these patterns are also consistent with the Daughter-Guarding Hypothesis, proposing that parents are especially motivated to safeguard daughters' sexual reputation and mate value more than that of sons (Perilloux et al., 2008). Mothers are particularly well positioned to provide mating guidance to daughters because their own life histories may make them especially attuned to the cues and contexts that jeopardise daughters' mating prospects. The relative lack of mating guidance for sons, and the greater sexual permissiveness when it does occur, aligns with the historically lower obligate reproductive costs and risks associated with male sexual activity (Trivers, 1972). Mothers and fathers might accrue inclusive fitness benefits when sons sexual activity is tolerated or encouraged, rather than restricted.

These sex-differentiated patterns of providing mating and relationship guidance are not merely attitudinal, but are associated with fitness-relevant consequences: a meta-analysis found that adolescents who discussed sexual safety with their parents, but especially daughters who discussed it with their mothers, tended to delay sexual activity and engage in safer sex (Widman et al., 2016). Together, these results suggest that parental investment patterns in mating and relationship guidance and sexual permissiveness function to calibrate offspring behaviour in ways that enhance their reproductive success, and thereby the parents' inclusive fitness.

Athletics and Physical Training, Competitive Encouragement, Mechanical and Practical Skills

Consistent with our predictions, sons received more investment than daughters in athletics and physical training and in competitive encouragement. However, no offspring-sex difference was found in mechanical and practical skills. Fathers invested more than mothers in athletics and physical training, and in mechanical and practical skills, and showed a significant father-son interaction indicating a bias toward sons. The mother-father difference in competitive encouragement was nonsignificant, indi-

cating that sons' greater competitive encouragement occurred similarly from both parents.

The observed patterns in athletics and physical training are congruent with prior research. Parents tend to provide more facilitation in sports to sons (Horn & Horn, 2007; Welk et al., 2003). Father-son dyads often involve direct co-participation and active skill transmission, with fathers drawing on their own sporting experience to provide practice opportunities and guidance (Erikstad et al., 2025). Evidence further shows that fathers who train their sons in sports often describe the experience as deeply meaningful, taking pride in their sons' achievements and viewing coaching as a way to spend quality time, teach skills and values, and share positive social interactions (Weiss & Fretwell, 2005).

Our findings regarding competitive encouragement also align with previous research. Even in highly gender-egalitarian societies such as Norway, both mothers and fathers are more likely to place sons than daughters in competitive contexts, selecting tournament-style reward schemes over non-competitive ones across a range of economic choice tasks (Tungodden & Willén, 2023). Likewise, even when men and women perform equally well, men possess stronger preferences for competitive reward structures, such as tournament-based compensation (Niederle & Vesterlund, 2007). These patterns support the notion that sexual selection has favoured greater competitiveness in males due to recurrent challenges related to status and resource acquisition, and that parents may further amplify these evolved differences through differential encouragement of competitive behaviour in sons.

Our finding that fathers invested more than mothers in mechanical and practical skills, and especially so for sons, is consistent with our hypotheses. This pattern is also reflected in the ethnographic record (Lew-Levy et al., 2017). In the Penan peoples of Borneo, the Chabu peoples of Ethiopia, the Batek peoples of Malaysia, and the Jenu Kuruba peoples of Southern India, it's fathers that teach sons to make and use tools and weapons for hunting (Demps et al., 2012; Lye, 1997; Puri, 2005; Terashima & Hewlett, 2016). In addition to these ethnographic patterns, experimental work shows that even at 3–5 years of age, boys exhibit stronger transmission of tool-use skills than girls, suggesting that some domain-specific sex-differentiated learning biases emerge early in development (Flynn & Whiten, 2008). The convergence of ethnographic and developmental evidence suggests that sex differences in mechanical and practical skill acquisition are not products of contemporary socialisation but reflect evolved predispositions, which are subsequently amplified through father-son transmission.

The absence of a daughter-son difference in mechanical and practical skills (when averaged across both parents) might reflect the limited scope and contemporary focus of this domain. The items referred to teaching how to "build things", and drive cars—the latter of which has little relevance to the adaptive problems faced in ancestral environments. Future studies should broaden this domain to capture more evolutionarily relevant forms of investment, such as teaching how to hunt, fish, use tools, craft, and sew. Such expansion must also include ancestrally female-typical technical competencies documented across hunter-gatherer societies, including food

processing, plant extraction, hide preparation, and clothing or fibre manufacture (Halperin, 1980).

The instrument used in our study assessed athletics and physical training specifically in regard to sport. Future research should broaden this domain to include other physically interactive forms of parental investment, such as physical and "rough-and-tumble" play—father-biased behaviours linked to the development of social competence, emotional skills, and self-regulation in offspring (Craig, 2006; Paquette et al., 2003; St-George et al., 2021; St-George & Freeman, 2017), all of which carry substantial fitness consequences.

Direct Care and Domestic Support, Bonding and Emotional Support, Social and Moral Guidance

As predicted, daughters and sons received equivalent levels of direct care and domestic support, and bonding and emotional support. The predicted daughter advantage in social and moral guidance, however, was not supported. Also in line with predictions, mothers provided more investment than fathers across all three domains. No parent × offspring sex interactions were found.

The maternal-bias found in these three domains is consistent with studies showing that, across cultures and socioeconomic classes, mothers tend to engage in significantly more parental care involving feeding, dressing, holding, cuddling, talking, and listening (Dede Yildirim & Roopnarine, 2019; Redshaw & Henderson, 2013; Roopnarine et al., 2021). In a study of 9 countries, Putnick et al. (2012) found that mothers reported more warmth toward offspring than fathers did in all but one country. The maternal predominance in such investments holds across diverse societies, with only rare exceptions (e.g., in the Aka peoples of the Central African Republic; Hewlett & Macfarlan, 2010).

From an evolutionary perspective the maternal-bias in these domains found in our study is straightforward to interpret. Over evolutionary time, mothers' greater minimum obligatory investment in gestation, childbirth, lactation, and prolonged proximity to offspring, created selection pressures for psychological and motivational systems that support nurturing, feeding, soothing, and early socialisation of offspring. Consequently, maternal investment is expected to be concentrated in precisely the domains encompassing direct care, bonding, and social guidance.

Although the predicted daughter advantage in social and moral guidance was not supported, this likely reflects limitations of the instrument used. Within the overarching category of social and moral guidance, there are likely multiple sub-domains. Guidance concerning sexual conduct, coalitions and status, or family and interpersonal obligations, for example, may differ between daughters and sons for reasons discussed previously. Our instrument did not distinguish between such sub-domains, and thus sex-linked patterns may have been masked. Future work should therefore separate social and moral guidance into evolutionarily meaningful sub-domains.

Discipline and Regulation

As predicted, mothers provided more discipline and regulation, and levels of discipline and regulation were equivalent for daughters and sons. No parent × offspring sex interaction was found in this domain.

Our finding that mothers provided more discipline, and that daughters and sons received comparable levels of discipline, is congruent with other research. Mothers tend to engage in more disciplinary commands and physical interference with young offspring than fathers, even when controlling for parental work hours (Hallers-Haalboom et al., 2016). Mothers report significantly more harsh verbal discipline toward 13–14 year old offspring than fathers, with no daughter-son differences (Wang & Kenny, 2014). Mothers also tend to spank their offspring more than fathers do (Lee et al., 2015). A systematic review of 31 studies likewise found that mothers are perceived as more behaviourally controlling than fathers (Yaffe, 2023). And a meta-analysis of 126 studies found no overall difference in parental control between daughters and sons (Endendijk et al., 2016).

From an evolutionary perspective, the maternal predominance in discipline is understandable. Throughout human evolution, mothers were the primary continuous caregivers, spending more total time in proximity to dependent offspring. This sustained involvement would have selected for motivational systems geared toward regulating behaviour, enforcing routines, and maintaining daily structure—functions that map closely onto discipline and regulation.

Protection

As predicted, there was no parent difference in protection. Contrary to predictions, however, daughters received more protection than sons. No parent × offspring sex interaction was observed. Interpretation of these findings is limited by the fact that protection was assessed using a single, undifferentiated item, which likely captured a broad mix of behaviours (e.g., physical protection, monitoring of social environments, and guarding against sexual risks). As such, responses may partly reflect overall exposure or time spent with each parent, rather than clearly differentiated forms of investment.

Although prior work often suggests a maternal bias in protection (e.g., Shepard, 1980; Brussoni et al., 2013), and fathers sometimes endorse lower levels of protectiveness, particularly in the context of risk taking (Brussoni & Olsen, 2013; Creighton et al., 2017), these patterns may depend on the specific form of protection being considered. Similarly, the observed daughter bias is consistent with broader claims that females are subject to greater protection or control (Stewart-Williams et al., 2022), and with domain-specific predictions such as the Daughter-Guarding Hypothesis (Perilloux et al., 2008; Wilson et al., 2010). However, because different forms of protection are likely shaped by distinct adaptive problems, collapsing them into a single item may obscure meaningful parent- and sex-differentiated patterns. Future work should therefore assess these sub-domains separately.

Wisdom and Life Guidance

Contrary to predictions, mothers provided more wisdom and life guidance than fathers. But, as expected, daughters and sons did not differ significantly. There was no parent × offspring sex interaction.

We had anticipated no mother-father difference because, although mothers and fathers possess partly overlapping and partly distinct life experiences, the broad range of contexts in which parents can impart guidance should, in principle, yield comparable levels of wisdom transmission.

Cross-cultural work, however, shows that women, and especially mothers, often serve as primary transmitters of interpersonal, relational, and moral wisdom. Among the Guji-Oromo peoples of Ethiopia, and the Mara Naga community of India, mothers and female elders primarily convey cautionary folktales, cultural knowledge, customs, and taboos (Huidina & Yamsani, 2024; Jirata, 2014). In a Polish sample, mothers' intergenerational stories centred on interpersonal relationships and emotions, whereas fathers' narratives more often described challenges, adventures, and personal achievements or failures (Mazurek, 2024). Related research shows that mothers reminisce in a more elaborative and emotionally expressive manner, and fathers more often emphasise achievement (Buckner & Fivush, 2000; Fivush & Zaman, 2015; Zaman & Fivush, 2011). These studies document differences in the content of wisdom transmitted by mothers and fathers, but not daughter-son differences in the amount of guidance, which aligns with our results.

Mothers also provide more socially embedded and emotionally elaborative investment across domains such as bonding, direct care, and social and moral guidance. This broader pattern is relevant because the items in our wisdom and life guidance domain—sharing experiences, discussing mistakes, helping to solve problems, and offering advice—map closely onto the relational and emotionally expressive forms of guidance that mothers disproportionately provide.

From an evolutionary perspective, the maternal bias in wisdom transmission is thus understandable. Helping offspring interpret experiences, avoid repeating errors, and navigate social or practical difficulties requires awareness of children's daily activities and emotional states. Across human evolution, mothers' continuous proximity to dependent offspring made them more likely to be present when problems arose and better positioned to offer contextually informed guidance. This ecological pattern would have favoured specialisation in experience-based instruction, consistent with the mother-biased pattern we observed.

Parent-offspring transmission of wisdom is not trivial. Parental wisdom enhances adolescents' social intelligence and emotional competence, and these effects operate mainly through mother-daughter and father-son dyads (Zare Mazloom et al., 2024). Because these capacities shape later social, mating, and parenting outcomes, wisdom and life guidance represents a parental investment domain with clear fitness implications worthy of further research.

Material Provision

Daughters received more material provision than sons, counter to prediction. But, as predicted, there was no mother-father difference. We found no parent × offspring sex interaction in this domain. Our material provision measure reflected direct resource inputs such as financial help, food, housing, and gifts. These forms of investment support baseline welfare rather than sex-specific developmental demands, so we expected this domain to be sex-neutral.

Two lines of research might offer partial context to our results. First, cues of financial recession can lead people to favour daughters in resource allocations (Durante et al., 2015). The authors interpreted this through the Trivers-Willard hypothesis, which holds that under adverse conditions parents are expected to bias investment toward daughters, whose reproductive prospects are less condition-dependent (Trivers & Willard, 1973). Although informative, this mechanism is unlikely to generalise straightforwardly to our sample, which was not drawn from economically stressed populations. Second, evidence from the Tsimane peoples of the Bolivian Amazon shows that when mothers possess more modern material assets, their daughters' nutritional status improves more than their sons', whereas fathers' assets tend to benefit sons more than daughters (Godoy et al., 2006). Experimental work in higher-income settings also reports a same-sex identification bias in forced-choice spending, with mothers favouring daughters and fathers favouring sons (Nikiforidis et al., 2018). These patterns typically involve differences between mothers and fathers or interactions with parent sex, neither of which appeared in our data.

As our finding of a daughter advantage in material provisioning is also inconsistent with this literature, we remain cautious with interpretation. This pattern was not anticipated for our sample, but empirical work shows that daughter-biased allocation can emerge under particular psychological or ecological conditions. Identifying the proximate cues that generate such asymmetries is an important direction for future work.

Education and Career Support

As predicted, we found no mother-father or daughter-son differences, and no parent × offspring sex interaction. This aligns with prior work showing little overall difference in parental involvement in offspring education between mothers and fathers (Kim & Hill, 2015). Apparent gaps largely reflect greater maternal involvement in school-based activities, whereas studies distinguishing school- and home-based involvement typically find little or no difference in at-home academic support (Kim & Hill, 2015; Shumow & Miller, 2001), which is most relevant to our measure.

Regarding offspring sex, some studies report greater parental involvement with daughters (Carter & Wojtkiewicz, 2000), although evidence suggests these patterns are conditional. In rural China, for example, parental expectations can shift between favouring daughters or sons depending on local resources and norms (Wang & Chen, 2024), and work in Tanzania shows that educational investment depends on livelihood and opportunity costs, with daughters sometimes receiving more schooling (Hedges et al., 2016). Related findings from African samples indicate Trivers-Wil-

lard-type effects, with poorer families investing more in daughters and wealthier families more in sons (Borgstede & Scheunpflug, 2023), a pattern also observed in the USA (Hopcroft & Martin, 2014). Such daughter-son differences appear to require substantial variation in resources and payoffs to education, conditions unlikely to characterise our sample.

Consistent with our null effects, parental influence on adolescents' educational and occupational values shows little variation by parent or offspring sex (Jodl et al., 2001), and reviews of career socialisation similarly report few systematic sex asymmetries (Whiston & Keller, 2004). Even in male-typed domains such as engineering, parental effects show no stable sex biases once family composition is accounted for (Jacobs et al., 2017).

Taken together, sex-differentiated educational investment appears to emerge primarily under ecological conditions in which payoffs to educating sons and daughters diverge. Absent such conditions, parental involvement shows minimal sex bias. Our findings are consistent with this pattern. In WEIRD (Western Educated Industrialized Rich and Democratic; Joseph Henrich et al., 2010) samples, education and career support appears to be a domain in which parents provide broadly similar expectations and encouragement to daughters and sons, consistent with evidence that women often match or exceed men in educational attainment (Stoet & Geary, 2020).

Theoretical Integration and Broader Implications

Potential Adaptations in Parents and Offspring

The findings from the present study raise, but do not answer, several key questions. Accordingly, the following considerations are necessarily speculative. One question is, have mothers and fathers evolved specialised parental adaptations to invest in their children in domain-specific and sex-specific ways? On this hypothesis, over human evolutionary history, parents who directed investment in these ways would have produced offspring who achieved greater survival and reproductive success than parents who invested indiscriminately.

If such parental adaptations exist, they should exhibit identifiable design features. Parents may possess parent-sex- and offspring-sex-linked allocation biases that direct investment toward domains aligned with sex-specific evolutionary histories and expected marginal returns for sons versus daughters. Investment may also be sensitive to offspring cues of interest, receptiveness, and aptitude, and therefore be contingent and calibrated. Sustained investment in domains with persistently low returns would have carried opportunity costs and is therefore unlikely to characterise evolved adaptations. Accordingly, parents may monitor offspring improvement in specific domains, and adjust allocation accordingly, intensifying, maintaining, reducing, or redirecting investment as marginal returns change.

A second, question is whether offspring have evolved specialised adaptations to evoke specific forms of parental investment. As males and females historically faced many different recurrent adaptive problems, offspring may possess sex-linked aptitude and motivational systems that bias them toward particular domains and toward evoking parental investment within them. Offspring may seek, solicit, and reinforce

investment in domains aligned with their predispositions, persisting where potential returns are high and disengaging where they are low. Although psychological research has often focused on causal arrows running from parents to children, evidence indicates that children also evoke behaviour from parents (e.g., Buss, 1981; Scarr & MacCartney, 1983).

Taken together, these hypotheses imply that parental investment and offspring responsiveness form a dynamically interacting system (Scarr, 1992, 1993; Scarr & MacCartney, 1983). Domain-specific and sex-specific patterns of parental investment would be expected to emerge from the interplay between parental predispositions, offspring predispositions, and ongoing feedback about returns, rather than from indiscriminate attempts by parents to socially mould their children.

Evolutionary Mismatch

A related key direction centers on evolutionary mismatches—the ways in which modern environments differ from those in which humans evolved (Tooby & Cosmides, 1990). The patterns of domain-specific and sex-specific forms of investment may have had tremendous importance on outcomes ancestrally, but not in modern environments in which survival is virtually guaranteed. Competitive success and mating success are influenced by highly modern technologies such as years of formal education, success as business entrepreneurs, cosmetic surgery and so on. These evolutionarily novel environments may have severed historical links between parental investment and offspring outcomes.

Do Sex Differences Precede Parental Socialisation? Reconciling Evolutionary and Sociocultural Accounts

Finally, our findings have implications for theories of socialisation. They are consistent with our evolutionary account in which parental socialisation is domain-specific and sex-specific, rather than uniform across domains or symmetric across sons and daughters. On this hypothesis, parental investment reflects context-dependent allocation rules that bias investment toward domains historically associated with higher fitness returns, while remaining sensitive to offspring sex and cues of responsiveness, aptitude, and evocation. Socialisation thus operates to amplify pre-existing predispositions in offspring rather than impose culturally arbitrary roles (Low, 1989).

Sociocultural theorists have often argued that sex-differentiated traits and preferences arise primarily through socialisation (e.g., Bussey & Bandura, 1999; Eagly & Wood, 1999; West & Zimmerman, 1987). The sex-differentiated parental investment observed in our data might therefore be taken as evidence that parents *cause* such differences. However, this interpretation may reverse the causal direction. From an evolutionary perspective, parents are hypothesised to respond to pre-existing sex differences that emerged because males and females historically faced selection from different adaptive problems. Parental biases such as investing more in athleticism toward sons, for example, may therefore have evolved because developing these competencies in sons historically yielded higher fitness returns. Moreover, offspring

are not passive recipients of parental input. They are expected to possess sex-linked predispositions that bias their interests, motivations, and receptivity to specific forms of investment.

A phylogenetic perspective further clarifies the likely causal ordering. Many sex differences in behaviour, such as male propensity for competitiveness, are evolutionarily ancient and widely observed across sexually reproducing species (Clutton-Brock & Huchard, 2013; Janicke et al., 2016; Kappeler et al., 2023). Parental socialisation involving the intentional transmission of skills and norms, however, evolved long after the male propensity for competitiveness, and is largely restricted to hominins (Gärdenfors & Högberg, 2017). It follows, therefore, that parental socialisation could not have generated this sex difference, but instead evolved later.

Taken together, this perspective helps reconcile evolutionary and sociocultural accounts (see also Al-Shawaf, 2025). In this view, parental socialisation plays an important role in transmitting information and skills that help offspring calibrate their behaviour to local ecological and social conditions (Lewis & Hoenig, 2021; Low, 1989). It is therefore best understood as part of evolved parent-offspring dynamics, rather than a culturally imposed alternative to biological explanations.

Limitations and Future Research

Several limitations qualify the present findings. Firstly, our sample is relatively limited in size, and it is thus crucial to replicate these findings in larger samples.

Certain domains, particularly the social ones, were too broad. Refining them into evolutionarily meaningful components, and distinguishing financial from direct forms of investment, will allow clearer tests of domain-specific predictions.

A key priority is cross-cultural research. Parental investment should vary with ecological factors such as resource availability, mating-system constraints, kin structure, and local sex ratios. Testing this framework across diverse populations will identify which patterns are ecologically contingent. This approach will also enable more precise tests of the Trivers-Willard hypothesis. Evidence for Trivers-Willard effects in humans is mixed (Thouzeau et al., 2023), possibly because most studies collapse parental investment into a single global measure. Splitting investment into specific, theoretically grounded domains allows clearer predictions about where condition-dependent biases should occur. Trivers-Willard effects may operate only in domains where investment would historically have yielded greater reproductive returns through sons or daughters.

Although our WEIRD sample limits generalisability, it may also underscore the robustness of parental investment sex biases: the predicted sex differences in parental investment emerge even in a modern Western context marked by strong pressures toward gender neutrality. Identifying when these biases strengthen, weaken, or reverse across cultures remains an important next step.

Finally, a further priority is to disentangle the respective contributions of parental and offspring adaptations in shaping domain-specific investment. The present study identifies systematic allocation patterns, but does not determine the extent to which these reflect evolved parental predispositions, offspring-evoked responses, or bidirectional calibration processes. Future research should examine whether parental

investment is calibrated to individual differences in offspring aptitude, receptiveness, or behavioural tendencies, and whether such calibration differs for sons and daughters. Distinguishing between parent-driven and child-evoked components of investment will be essential for refining evolutionary models of socialisation.

Conclusions

This study provides the first comprehensive, domain-specific test of sex-differentiated parental investment across a broad suite of functionally distinct behaviours. Clear patterns emerged in support of our hypotheses. Mothers provided more overall investment than fathers, and this difference was concentrated on daughters. Maternal biases were strongest in domains tied to nurturance, socialisation, and everyday regulation. Fathers, in contrast, invested more in athletics and physical training, and in mechanical and practical skills, showing a pronounced bias toward sons. Daughters received more mating and relationship guidance, protection, and material support, whereas sons received more permissiveness in sexual behaviour and greater investment in athletics, and competitive encouragement. Education and career support showed no reliable sex differences, consistent with evidence that such biases only emerge when ecological conditions create divergent payoffs to educating sons versus daughters. Overall, the observed patterns align closely with the hypothesis that parental investment tracks enduring, sex-differentiated adaptive problems, and remains unbiased in domains tied to challenges shared by daughters and sons.

These findings have direct implications for debates about the origins of sex differences. They are difficult to reconcile with accounts that attribute sex differences primarily to parental treatment. Yet, they align with the view that parents respond to, and amplify, evolved sex differences in the psychological and behavioural tendencies shaped by the distinct adaptive problems historically faced by males and females. On this account, parental investment not only addresses domain-specific survival and social demands, but can also enhance offspring mate value, thereby generating additional inclusive fitness returns. At the same time, the results highlight the need for finer-grained, evolutionarily informed measures of parental investment, and for cross-cultural studies conducted across diverse ecological contexts. Future work linking domain-specific investment to downstream outcomes in offspring will be crucial for clarifying how natural selection has shaped the architecture of human parental investment.

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Declarations

Competing interests The authors declare no competing interests.

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F. Sid Dougan is a PhD student in Evolutionary Psychology at The University of Texas at Austin. His research interests include inclusive fitness, kinship dynamics, familial conflict and cooperation, and parental investment. He previously completed an MSci in Zoology at University of Bristol, UK, where he focussed on the evolution and behavioural ecology of arthropods.

William Costello is a PhD student in Evolutionary Psychology at The University of Texas at Austin. His research focuses on human mating psychology, with particular interests in involuntary celibacy, cross-sex friendships, attractiveness-enhancement strategies, and cross-sex mindreading. He previously completed an MSc in Psychology, Culture, and Evolution at Brunel University London.

David M. Buss is a professor of psychology at The University of Texas at Austin and director of the Buss Lab. He is one of the founders of the field of Evolutionary Psychology. His research focuses on human mating strategies, including mate preferences, attraction, jealousy, infidelity, and mate retention, as well as conflict between the sexes, aggression, status, prestige, and reputation.

Authors and Affiliations

F. Sid Dougan[1] · **William Costello**[1] · **David M. Buss**[1]

✉ F. Sid Dougan
fsdougan@utexas.edu

[1] Department of Psychology, The University of Texas at Austin, Austin, TX, USA