



Gender stereotypes about interests start early and cause gender disparities in computer science and engineering

Allison Master^{a,b,1} , Andrew N. Meltzoff^{b,c} , and Sapna Cheryan^c

^aPsychological, Health, and Learning Sciences, University of Houston, Houston, TX 77204; ^bInstitute for Learning & Brain Sciences, University of Washington, Seattle, WA 98195; and ^cDepartment of Psychology, University of Washington, Seattle, WA 98195

Edited by Yarrow Dunham, Yale University, New Haven, CT, and accepted by the Editorial Board September 10, 2021 (received for review March 8, 2021)

Societal stereotypes depict girls as less interested than boys in computer science and engineering. We demonstrate the existence of these stereotypes among children and adolescents from first to 12th grade and their potential negative consequences for girls' subsequent participation in these fields. Studies 1 and 2 ($n = 2,277$; one preregistered) reveal that children as young as age six (first grade) and adolescents across multiple racial/ethnic and gender intersections (Black, Latinx, Asian, and White girls and boys) endorse stereotypes that girls are less interested than boys in computer science and engineering. The more that individual girls endorse gender-interest stereotypes favoring boys in computer science and engineering, the lower their own interest and sense of belonging in these fields. These gender-interest stereotypes are endorsed even more strongly than gender stereotypes about computer science and engineering abilities. Studies 3 and 4 ($n = 172$; both preregistered) experimentally demonstrate that 8- to 9-y-old girls are significantly less interested in an activity marked with a gender stereotype ("girls are less interested in this activity than boys") compared to an activity with no such stereotype ("girls and boys are equally interested in this activity"). Taken together, both ecologically valid real-world studies (Studies 1 and 2) and controlled preregistered laboratory experiments (Studies 3 and 4) reveal that stereotypes that girls are less interested than boys in computer science and engineering emerge early and may contribute to gender disparities.

STEM | inequities | gender | stereotypes | motivation

Societal stereotypes, shared beliefs linking groups and traits, have numerous negative consequences (1, 2). The prevalence of negative stereotypes about women's and girls' abilities contributes to gender disparities in computer science and engineering (3–8). Here, we investigate a different and consequential pervasive stereotype: that women and girls have lower interest in computer science and engineering. We define interest stereotypes as beliefs that one social group has lower liking, enjoyment, or predisposition to engage in a particular topic than another group. Interest stereotypes may influence motivation by altering students' perceptions of themselves, including their sense of whether they would belong with others in that field. The current studies make three primary contributions by demonstrating 1) the existence of gender-interest stereotypes favoring boys among young children and adolescents across multiple racial/ethnic and gender intersections in the United States, 2) that gender-interest stereotypes causally influence subsequent academic motivation (e.g., children's own interest in pursuing, choice of, and sense of belonging in computer science activities), and 3) that gender-interest stereotypes more strongly predict academic motivation to pursue computer science and engineering than the traditionally studied gender-ability stereotypes. Four studies ($n = 2,449$, 3 preregistered) combine cross-sectional surveys in schools across a wide range of ages and racial/ethnic groups with controlled experiments in the laboratory to investigate the presence, correlates, and causal

effects of gender-interest stereotypes on interest and participation in computer science and engineering activities and classes.

In the United States, the representation of women varies widely across science, technology, engineering, and math (STEM) fields. Computer science and engineering have among the largest gender disparities in college, much larger than mathematics, biology, and chemistry (9–11). Gender disparities in computer science and engineering contribute to many societal inequities, including the existence of products and services that overlook and sometimes selectively harm women and children (12). Gender disparities in lucrative fields such as computer science and engineering are also a significant source of the gender wage gap (13). Society would benefit from more girls and women pursuing these fields.

Current Studies

We combine large cross-sectional surveys (Studies 1 and 2, $Ns = 733$ and 1,544) and controlled preregistered laboratory experiments (Studies 3 and 4) to establish the existence of gender-interest stereotypes and their causal influence on academic motivation and participation. In Studies 1 and 2, we find that young children and adolescents endorse gender-interest stereotypes. These stereotypes negatively predict girls' interest in pursuing computer science and engineering and sense of belonging in these fields, even when controlling for effects of gender stereotypes about ability. In Studies 3 and 4, we find that girls are significantly less interested in an activity that is marked (through random assignment) by a gender-interest stereotype compared to an activity with no stereotype. We also find that these gender-interest stereotypes favoring boys are

Significance

Societal stereotypes that girls are less interested than boys in computer science and engineering are endorsed by children and adolescents in a large and socioeconomically diverse sample, across multiple racial/ethnic and gender intersections, and as early as age six (first grade). Gender-interest stereotypes may contribute to subsequent gender disparities in the pursuit of these societally important fields. Addressing interest stereotypes may help improve educational equity.

Author contributions: A.M., A.N.M., and S.C. designed research; A.M. performed research; A.M. analyzed data; and A.M., A.N.M., and S.C. wrote the paper.

The authors declare no competing interest.

This article is a PNAS Direct Submission. Y.D. is a guest editor invited by the Editorial Board.

This open access article is distributed under [Creative Commons Attribution-NonCommercial-NoDerivatives License 4.0 \(CC BY-NC-ND\)](https://creativecommons.org/licenses/by-nc-nd/4.0/).

¹To whom correspondence may be addressed. Email: amaster@uh.edu.

This article contains supporting information online at <http://www.pnas.org/lookup/suppl/doi:10.1073/pnas.2100030118/-DCSupplemental>.

Published November 22, 2021.

sometimes (but not always) positively related to boys' interest and sense of belonging.

This programmatic series of four studies advances theory by demonstrating that gender-interest stereotypes 1) exist among a racially and socioeconomically diverse group of children and adolescents across multiple racial/ethnic and gender intersections, 2) more strongly predict girls' motivation to pursue computer science and engineering courses than gender-ability stereotypes, 3) cause girls to be less interested than boys in pursuing novel and computer science-related activities, and 4) cause girls to have a lower sense of belonging which mediates their lower interest in computer science activities. These studies also have several methodological strengths: 1) mixed methods, including large-scale surveys administered in schools and pre-registered laboratory experiments, 2) a racially and socioeconomically diverse US sample, 3) intersectional analyses (i.e., effects broken down by race and gender), 4) self-report and behavioral choice outcomes to measure interest and participation, and 5) in-person and online video-conferencing procedures, similar to how the majority of American children experienced learning situations during the COVID-19 pandemic (14).

Study 1: Survey

Rationale. Study 1 ($n = 733$) examined whether children in grades 3 through 7 endorsed gender-interest stereotypes favoring boys in computer science, how their endorsement of gender-interest stereotypes compared to their endorsement of gender-ability stereotypes, and how those stereotypes predicted children's interest and sense of belonging in pursuing computer science. Most of the children in the study were White (72%), and most children in these districts were from middle- and upper-class households (Study 2 included a larger sample in a more racially and economically diverse district).

Results.

Children endorsed gender-interest stereotypes favoring boys. Children significantly endorsed gender-interest stereotypes favoring boys in computer science, $t(713) = 4.69$, $P < 0.001$, and $d = 0.18$ (Fig. 1 and *SI Appendix, Table S1*). More than one-third (36%) of children believed that girls are less interested than boys in computer science compared to 18% of children who believed that girls are more interested than boys (refer to *SI Appendix, Fig. S1* for distribution of responses). Boys showed particularly strong endorsement ($M = 0.39$,

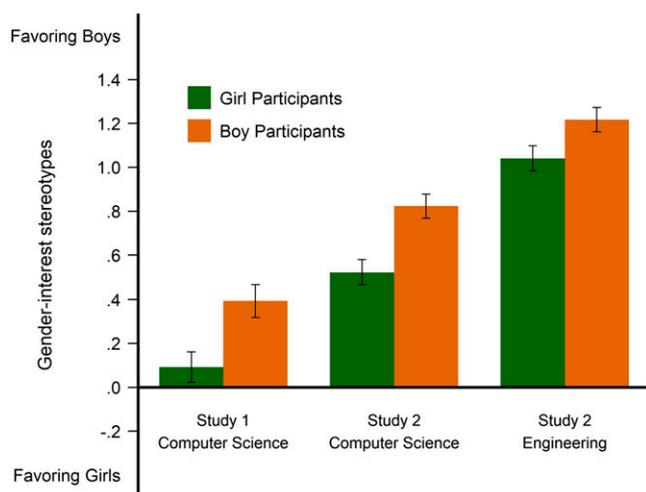


Fig. 1. Studies 1 and 2: Gender-interest stereotypes by participant gender. Girls' (green bars) and boys' (orange bars) gender-interest stereotypes (range, -5 to 5). Error bars represent ± 1 SE.

$SD = 1.33$), $t(320) = 5.28$, $P < 0.001$, and $d = 0.29$ and were significantly more likely than girls ($M = 0.09$, $SD = 1.34$, $t[371] = 1.32$, $P = 0.19$, and $d = 0.07$) to endorse gender-interest stereotypes, $t(676.77) = 2.96$, $P = 0.003$, and $d = 0.23$ (refer to *SI Appendix* for an explanation for why girls may not have significantly endorsed gender-interest stereotypes in this study). Children endorsed gender-interest stereotypes in computer science in third grade, $P = 0.007$, and $d = 0.24$ and at every grade level thereafter through seventh grade with one exception (refer to Fig. 2 for endorsement of stereotypes by grade).

Gender-interest stereotypes were correlated with interest in pursuing computer science differentially by gender. Children were also asked about their own interest in pursuing computer science. In line with prior research (15), girls reported significantly lower interest in pursuing computer science than did boys, $t(669.62) = 2.63$, $P = 0.009$, and $d = 0.20$. The more that individual girls endorsed gender-interest stereotypes favoring boys in computer science, the lower their own interest in pursuing computer science, $r(369) = -0.26$ and $P < 0.001$ (*SI Appendix, Table S2*). For boys, the more they endorsed gender-interest stereotypes favoring boys in computer science, the greater their

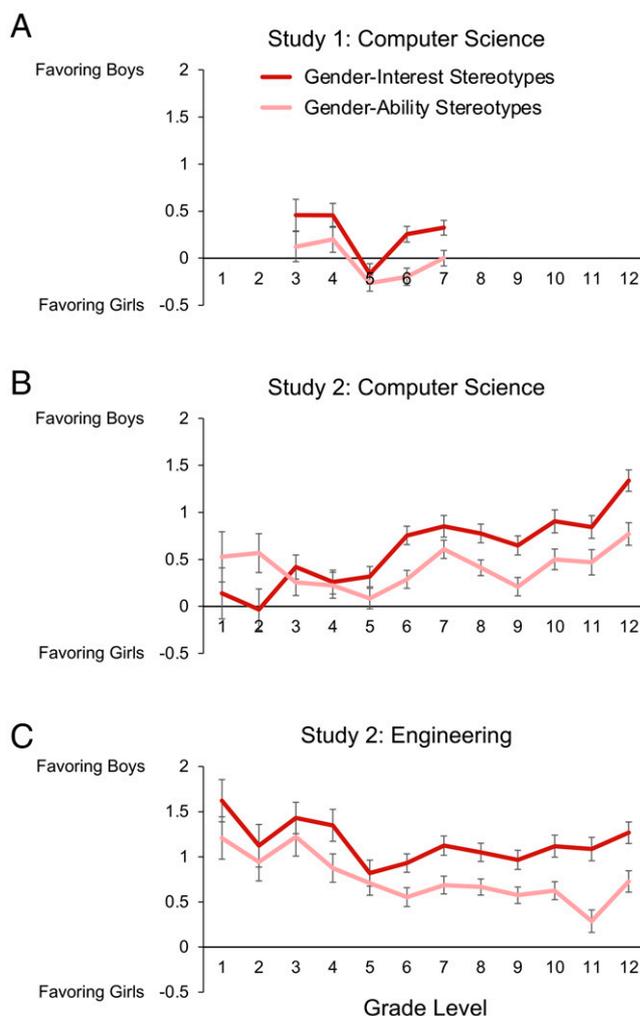


Fig. 2. Studies 1 and 2: Gender-interest and gender-ability stereotypes by grade and field. Endorsement of gender-interest (darker line) and gender-ability (lighter line) stereotypes in computer science in Study 1 (A) and Study 2 (B) and engineering in Study 2 (C) by grade level. Positive numbers represent stereotype difference scores favoring boys, and negative numbers represent stereotype difference scores favoring girls (range -5 to 5). Error bars represent ± 1 SE.

own interest in pursuing computer science, $r(315) = 0.16$ and $P = 0.003$.

Gender-interest stereotypes were endorsed more strongly and were more predictive of girls' interest than gender-ability stereotypes. Children also reported how good girls (“How good are most girls at computer science?”) and boys (“How good are most boys at computer science?”) are at computer science. Gender-interest and gender-ability stereotypes were distinct but moderately correlated, $r(701) = 0.48$ and $P < 0.001$. Gender-interest stereotypes were endorsed significantly more strongly than gender-ability stereotypes, $t(702) = 6.26$, $P < 0.001$, and $d = 0.24$ (Fig. 2), which were not endorsed in this study, $P = 0.14$ and $d = -0.06$. When including both stereotypes simultaneously as predictors of girls' own interest in pursuing computer science, only gender-interest stereotypes predicted girls' own interest, $P < 0.001$ versus $P = 0.75$ (Fig. 3 and *SI Appendix, Table S3*), with a significant difference between the two stereotypes, $Z = 2.48$ and $P = 0.013$. For boys, only gender-ability stereotypes predicted boys' own interest, $P = 0.011$ versus $P = 0.12$, with no significant difference between the two stereotypes, $Z = 0.55$ and $P = 0.58$.

Sense of belonging mediated relation between gender-interest stereotypes and girls' lower interest in pursuing computer science. Girls may reason that if their group is supposedly not interested, then they are not likely to belong in the field (7, 16, 17). Not having a sense of belonging is a powerful deterrent for students (18–21). We therefore also assessed children's sense of belonging in computer science classes and activities. For girls, the relation between endorsement of gender-interest stereotypes favoring boys and their own lower interest in pursuing computer science was mediated by a lower sense of belonging in computer science classes and activities, conditional indirect effect = -0.14 , 95% CI $[-0.24, -0.03]$ (*SI Appendix, Table S4*). The mediation was in the opposite direction for boys, as boys' greater sense of belonging mediated the positive relation between endorsement of gender-interest stereotypes favoring boys and interest in pursuing computer science; conditional indirect effect = 0.10 , 95% CI $[0.02, 0.18]$, and the overall index of moderated mediation = -0.24 , 95% CI $[-0.37, -0.10]$ (*SI Appendix, Fig. S2*). The stereotype that girls are less interested in computer science may send girls a signal that they do not belong and dissuade them from developing an interest in these fields (while sending boys the opposite signal).

Study 2: Generalizability with a More Diverse Sample

Rationale. We conducted Study 2 ($n = 1,544$; preregistered; *SI Appendix*) with students in grades 1 through 12 to replicate Study 1 findings and generalize them to questions about engineering among a larger and more racially/ethnically diverse sample (37% White, 24% Latinx, 15% multiracial, 9% Asian,

8% Black, 1% Native American, 3% another racial group, and 3% no response) from a school district in which 43% of students receive free/reduced-price lunch.

Results.

Students endorsed gender-interest stereotypes about computer science and engineering across gender, racial/ethnic groups, and their intersections. Students endorsed gender-interest stereotypes favoring boys in computer science, $t(1,531) = 17.16$, $P < 0.001$, and $d = 0.44$, and engineering, $t(1,529) = 28.47$, $P < 0.001$, and $d = 0.73$ (Fig. 1 and *SI Appendix, Fig. S1*). More children believed that girls are less interested than boys in computer science (51%) and engineering (63%) compared to children who believed that girls are more interested than boys in computer science (14%) and engineering (9%). Both girl and boy participants endorsed gender-interest stereotypes favoring boys in computer science (girls: $M = 0.52$, $SD = 1.53$, $t[741] = 9.34$, $P < 0.001$, and $d = 0.34$; boys: $M = 0.82$, $SD = 1.50$, $t[744] = 14.95$, $P < 0.001$, and $d = 0.55$) and engineering (girls: $M = 1.04$, $SD = 1.56$, $t[741] = 18.22$, $P < 0.001$, and $d = 0.67$; boys: $M = 1.22$, $SD = 1.52$, $t[742] = 21.81$, $P < 0.001$, and $d = 0.80$). Boys were significantly more likely than girls to endorse gender-interest stereotypes favoring boys in computer science, $t(1,484.42) = 3.82$, $P < 0.001$, and $d = 0.20$, and engineering, $t(1,482.16) = 2.21$, $P = 0.03$, and $d = 0.11$ (*SI Appendix, Table S1*). Gender-interest stereotypes favoring boys were endorsed by Black, Asian, Latinx, and White girls and boys for both computer science and engineering, all P s < 0.03 (Table 1).

Gender-interest stereotypes in computer science and engineering were present early and across ages. Children and adolescents in every grade level endorsed gender-interest stereotypes favoring boys in engineering, P s < 0.001 , including first grade, $P < 0.001$ and $d = 0.71$ (Fig. 2). Children and adolescents endorsed gender-interest stereotypes in computer science starting in third grade, $P = 0.002$ and $d = 0.35$, and in every grade level thereafter, P s < 0.05 (Fig. 2). The inclusion of a larger range of higher grades may have contributed to the apparent stronger endorsement of gender-interest stereotypes in Study 2 compared to Study 1.

Gender-interest stereotypes were correlated with girls' lower interest in pursuing computer science and engineering for girls from multiple racial/ethnic groups. The more girls endorsed gender-interest stereotypes favoring boys, the lower their own interest in pursuing computer science, $r(737) = -0.25$ and $P < 0.001$, and engineering, $r(736) = -0.32$ and $P < 0.001$ (*SI Appendix, Table S5*). Gender-interest stereotypes predicted lower interest in pursuing computer science for Black, Asian, Latina, and White girls, all r s < -0.20 and P s < 0.004 (*SI Appendix, Table S6*). Gender-interest stereotypes also predicted lower interest in pursuing engineering for Black, Asian, and

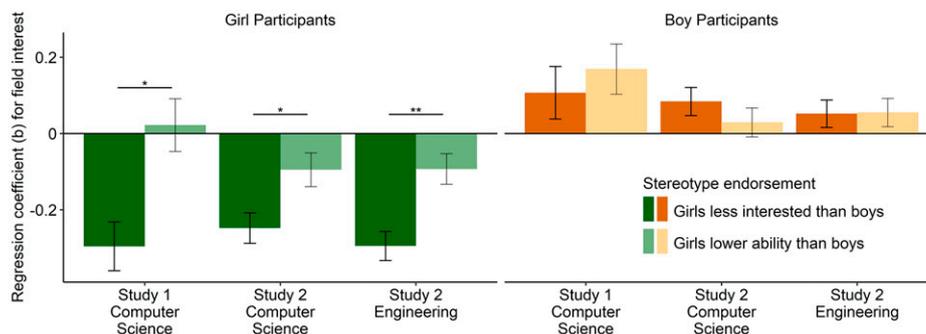


Fig. 3. Studies 1 and 2: Regression coefficients of the relation between stereotypes and interest by gender. Girls' (green bars) and boys' (orange bars) gender-interest (darker bars) and gender-ability (lighter bars) stereotypes in computer science and engineering and their own interest in pursuing computer science and engineering. Regressions included both types of stereotypes as predictors. Error bars represent ± 1 SE. * $P < 0.05$ and ** $P < 0.01$.

Table 1. Study 2 Means and SDs for Gender-Interest Stereotypes by Race/Ethnicity

Field	Race/ Ethnicity	Girl participants (n = 579)			Boy participants (n = 601)		
		N	M	SD	N	M	SD
Computer science	Black	52	0.60*	1.82	69	1.13***	1.78
	Asian	66	0.74***	1.29	79	0.80***	1.24
	Latinx	190	0.56***	1.27	166	0.73***	1.41
	White	269	0.51***	1.53	281	0.88***	1.52
Engineering	Black	52	1.15***	1.93	68	1.43***	1.65
	Asian	66	1.03***	1.16	79	1.27***	1.64
	Latinx	190	1.16***	1.52	166	1.17***	1.41
	White	269	0.95***	1.44	281	1.24***	1.54

Note: Stereotypes are difference scores between ratings about boys and ratings about girls (range -5 to 5). Positive values correspond to stereotypes favoring boys. N represents number. M represents mean. Difference from scale midpoint (0): * $P < 0.05$ and *** $P < 0.001$.

White girls, $r_s < -0.29$ and $P_s < 0.02$, but not Latina girls, $P = 0.11$. The more boys endorsed gender-interest stereotypes favoring boys, the higher their own interest in pursuing computer science, $r(742) = 0.09$ and $P = 0.012$, and engineering, $r(740) = 0.08$ and $P = 0.037$ (refer to *SI Appendix, Table S6* for boys' ethnicity/ethnicity). The relation between gender-interest stereotypes favoring boys and own interest in pursuing computer science was mediated by a lower sense of belonging in computer science for girls, conditional indirect effect = -0.08 , 95% CI $[-0.13, -0.03]$, and by a greater sense of belonging for boys, conditional indirect effect = 0.04 , 95% CI $[0.002, 0.08]$; the overall index of moderated mediation = -0.12 , 95% CI $[-0.18, -0.06]$ (*SI Appendix, Table S4*).

Gender-interest stereotypes were more strongly endorsed and predicted girls' interest more strongly than gender-ability stereotypes. In Study 2, students endorsed gender-ability stereotypes favoring boys in computer science, $P < 0.001$ and $d = 0.29$, and engineering, $P < 0.001$ and $d = 0.48$ (*SI Appendix, Table S1*). Supporting our preregistered hypotheses, gender-interest stereotypes favoring boys were endorsed more strongly than gender-ability stereotypes in computer science, $t(1,526) = 5.44$, $P < 0.001$, and $d = 0.14$, and engineering, $t(1,526) = 9.31$, $P < 0.001$, and $d = 0.24$. Supporting our preregistered hypotheses, when including both types of stereotypes simultaneously as predictors of girls' own interest, gender-interest stereotypes were a significantly larger predictor of interest than gender-ability stereotypes in pursuing computer science, $Z = 2.04$ and $P = 0.04$, and engineering, $Z = 2.86$ and $P = 0.004$ (Fig. 3 and *SI Appendix, Table S3*). When including both types of stereotypes simultaneously as predictors of boys' interest, only gender-interest stereotypes predicted boys' interest in computer science, $P = 0.023$, and neither predicted interest in engineering, $P_s > 0.13$.

Study 3: Laboratory Experiment to Show Causal Consequences on Girls' Interest and Choices for a Novel Activity

Rationale. Studies 1 and 2 demonstrated a consistent relation between gender-interest stereotypes and girls' lower interest in pursuing computer science and engineering. Yet it remains critical to demonstrate the direction of causality. Gender-interest stereotypes favoring boys may cause girls to become less interested in pursuing these fields (16, 17). Alternatively, girls who are less interested in these fields may use their own low interest as the basis for endorsing stereotypes that other girls have low

interest as well (22). The value of the experimental approach used in Studies 3 and 4 is that the manipulation of stereotypes allows the inference that stereotypes can cause reductions in girls' interest in pursuing computer science and engineering activities. In Study 3 ($n = 50$; preregistered), 8-y-old girls learned about two novel activities with experimentally manipulated descriptions, making this a within-subjects experiment. The descriptions were identical, except that an interest stereotype that girls were less interested in the activity than boys was either present (stereotyped) or absent (nonstereotyped). Using this experimental design allowed us to isolate whether the simple labeling of a novel activity as one that "girls are less interested in than boys" had a causal effect on girls' interest compared to the absence of that stereotype. We also gave girls the opportunity to choose one of the activities to take home to work on as a behavioral measure of participation. The novelty of the activities allowed us to ensure that girls had no existing stereotypes or expectations about them.

Results.

Gender-interest stereotypes caused girls to have lower interest in a novel activity. Supporting our preregistered hypothesis, girls were significantly less interested in the stereotyped activity (in which "girls are less interested than boys") than the nonstereotyped activity (in which "girls and boys are equally interested"), $t(49) = 5.46$, $P < 0.001$, and $d = 1.10$ (Fig. 4 and *SI Appendix, Table S7*). Also supporting our preregistered hypothesis, in the behavioral choice task, only 20% of girls chose to take home the stereotyped activity and the rest (80%) chose the nonstereotyped activity, binomial proportion test, $P < 0.001$.

Study 4: Laboratory Experiment to Show Causal Consequences on Gender Gaps in Computer Science

Rationale. Study 4 ($n = 122$; preregistered) replicated Study 3 and expanded it in two key ways. First, Study 4 examined whether the presence of a gender-interest stereotype would cause lower interest in a computer science activity among 8- to 9-y-old girls compared to the absence of a gender-interest stereotype. Second, Study 4 participants included boys as well to examine whether stereotypes can cause gender disparities in children's interest in a computer science activity. If gender gaps are larger when gender-interest stereotypes are present than when they are absent, this allows the inference that gender-interest stereotypes may widen gender disparities.

Results.

Gender-interest stereotypes created a gender gap in interest in a computer science activity. Supporting our preregistered hypothesis, a 2 (presence of stereotype: stereotyped, nonstereotyped) \times 2 (gender: girls, boys) ANOVA on interest revealed a significant interaction, $F(1,120) = 7.22$, $P = 0.008$, and $\eta_p^2 = 0.06$ (Fig. 4 and *SI Appendix, Table S7*). Supporting our preregistered hypothesis, girls were significantly less interested in the stereotyped activity than were boys, $P = 0.002$ and $d = 0.57$, and there was no gender difference in interest in the nonstereotyped activity, $P = 0.42$ and $d = 0.15$. Also supporting our preregistered hypothesis, girls were significantly less interested in the stereotyped than the nonstereotyped activity, $P < 0.001$ and $d = 0.69$, and there was no statistically significant difference between boys' interest in the stereotyped and the nonstereotyped activities, $P = 0.99$ and $d = 0.002$. Additionally supporting our preregistered hypothesis, girls were significantly less likely to choose to take home the stereotyped activity (35%) than the nonstereotyped activity (65%), binomial proportion test, $P = 0.03$. Boys were at chance (50% chose stereotyped, 50% chose nonstereotyped), $P = 1.00$. This gender difference in behavioral choice was in the predicted direction but did not reach significance as predicted by our preregistration, $\chi^2(1, n = 122) = 2.81$ and $P = 0.09$. Girls' lower interest

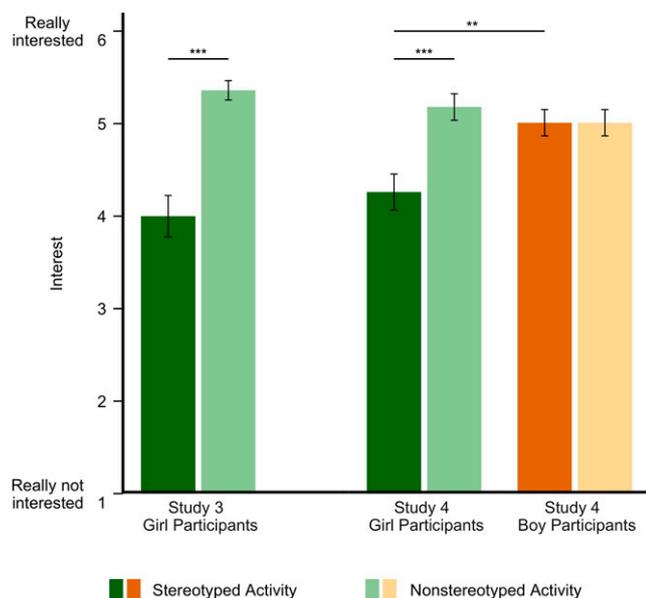


Fig. 4. Studies 3 and 4: Interest by gender and presence of stereotype. Interest in an activity that was randomly assigned through an experimental manipulation to be described with a gender-interest stereotype present (darker bars) or absent (lighter bars) for girls (green bars) and boys (orange bars) is shown. Error bars represent ± 1 SE. $**P < 0.01$ and $***P < 0.001$.

in the stereotyped versus nonstereotyped activity was mediated by their lower sense of belonging, indirect effect = -1.29 , $SE = 0.28$, and 95% CI $[-1.75, -0.64]$ (*SI Appendix, Table S4*). Belonging did not mediate effects for boys, indirect effect = -0.09 , $SE = 0.10$, and 95% CI $[-0.33, 0.08]$. In sum, gender differences in interest in a computer science activity were evident only when the computer science activity was linked to a gender-interest stereotype favoring boys and not when the gender-interest stereotype was not present.

General Discussion

These four studies show that stereotypes that girls have lower interest in computer science and engineering than boys are formed early and cause gender disparities in motivation for computer science and novel activities. Studies 1 and 2 reveal that these stereotypes are evident among young children (as early as age six, first grade), across multiple ages from childhood through adolescence, and across intersections of racial/ethnic identity and gender. Moreover, gender-interest stereotypes favoring boys predict girls' lower interest in pursuing computer science and engineering classes across multiple intersections of gender and racial/ethnic identity. Study 3 shows that the presence of these gender-interest stereotypes causes girls to have lower interest in a novel activity compared to when gender-interest stereotypes are absent, demonstrating their power beyond computer science and engineering. Study 4 demonstrates that gender-interest stereotypes favoring boys cause gender disparities in motivation for computer science activities by reducing girls' interest.

Gender-interest stereotypes show stronger links to girls' interest than gender-ability stereotypes. It is not the case that all negative stereotypes impact students' interest equally—effects were stronger for gender-interest stereotypes than gender-ability stereotypes (*SI Appendix, Study S1*). These findings are consistent with work showing that students' academic choices are typically driven more by their beliefs about their interest than beliefs about their abilities (23, 24). Certainly, both stereotypes may be linked to children's own subsequent motivation (3), but children's

gender-interest stereotypes may more strongly explain gender gaps in participation than their gender-ability stereotypes.

Why are gender-interest stereotypes so powerful? Gender-interest stereotypes predict and cause girls' reduced sense of belonging in computer science classes and activities. Sense of belonging is a potent psychological motivator (25) and predicts interest in computer science and engineering (18–21). Stereotypes can indirectly shape students' perceptions of whether they would belong with others in that field (e.g., “my group is less interested in this, so I would not belong, thus I'm less motivated to pursue it”) (7). Gender-interest stereotypes may also cause self-socialization or conformity-like effects, when a student assumes that their interest will follow the interests of others because “I am like them” (22, 26). Such effects could be moderated by identification with the group or other beliefs that disrupt the inferential link from group stereotypes to the self (27). These findings illustrate sense of belonging as one potential causal mechanism (of possibly many).

Our studies reveal four important insights about boys' gender-interest stereotypes. First, gender-interest stereotypes favoring boys are more strongly endorsed by boys than girls. Second, gender-interest stereotypes favoring boys in computer science predict a stereotype-lift effect (28) on boys' interest in Studies 1 and 2, but this stereotype-lift effect is absent for engineering in Study 2 and absent in Study 4. Third, a meta-analysis across Studies 1 and 2 finds no significant differences between girls and boys in how strongly gender-interest stereotypes (coded as favoring their own gender) predict interest in computer science (*SI Appendix*). Finally, an experimental study investigating a gender-interest stereotype favoring girls reveals that boys express less interest in an activity when that gender-interest stereotype is present versus absent (*SI Appendix, Study S1*). Boys' academic motivation may be vulnerable to the same processes to the extent that gender-interest stereotypes favoring girls exist in other fields, such as language arts (29).

These studies also indicate the developmental trajectories of both 1) the endorsement of gender-interest stereotypes and 2) links between stereotypes and motivation. First, children endorse gender-interest stereotypes favoring boys about engineering by first grade and about computer science by third grade. Endorsement of stereotypes about computer science and engineering generally remains strong through high school, with some suggestion that endorsement of computer science stereotypes increases among adolescents. This suggests that elementary school may be a particularly opportune time to introduce computer science to young girls, before stereotype endorsements firmly take root (7, 9, 15, 27). Second, girls' endorsement of these stereotypes is negatively correlated with their interest in computer science by elementary (Study 1) or middle school (Study 2) and with their interest in engineering by elementary school (Study 2; *SI Appendix, Tables S2 and S5*). These links between stereotypes and interest persist through high school. We note that because these data are cross-sectional, it would be desirable to conduct longitudinal studies to investigate how stereotype endorsement and links to motivation change over time within individual students. Overall, these findings suggest that educators who wish to promote girls' interest and engagement in STEM should consider using programs and activities designed to counteract these stereotypes (7) in their efforts to promote educational equity and draw more young girls to STEM.

Taking all four studies together, we can consider alternative explanations for the overall patterns uncovered. One alternative interpretation is that children's beliefs reflect an observed reality in the world rather than stereotypes (30). For instance, perhaps children observe fewer girls in optional computer science and engineering activities and infer that girls are less interested in these fields. However, many gender stereotypes are derived from people's observed reality (31), and that does not make

them any less potent or worthy of study. Moreover, we demonstrate that these stereotypes influence future disparities in the absence of observational experience or prior knowledge, as in Study 3, in which children were randomly assigned to learn that girls are less interested in a novel activity. Thus, gender-interest stereotypes influence children's interest even when invented. Cues of gender-interest stereotypes by teachers, parents, or peers may create new or widen existing gender gaps, even when the stereotypes have no basis in reality. In addition, people may draw on gender stereotypes to make discriminatory inferences about individuals (e.g., denying opportunities to girls because of an assumption they might not be interested when they actually are) (32). (Refer to *SI Appendix* for empirical tests of other alternative explanations, including whether overlap in wording or experimental demand/generalized negativity was driving results.)

The current studies documented short-term causal effects for a single activity within a carefully controlled laboratory environment; more work is now needed on how enduring such stereotypes are, how long their effects on motivation last, and how they contribute to the development of disparities in broader career interests and decisions in more complex contexts. Future work could examine stereotypes among students with different levels of experience with and definitions of computer science and engineering, with the aim of helping educators identify effective language that can generate interest among their students. Future work could also examine whether the norms against expression of gender-interest stereotypes are weaker than norms against expression of gender-ability stereotypes, potentially making gender-interest stereotypes more likely to spread and less likely to be counteracted. Finally, other mechanisms should also be investigated as potentially responsible for negative effects of gender-interest stereotypes, such as concerns about who one's peers in the field will be and how one will be seen by others inside and outside the field (33).

Based on converging evidence from multiple methods, including both ecologically valid real-world settings (Studies 1 and 2) and preregistered, controlled laboratory experiments (Studies 3 and 4), we suggest that interest stereotypes involving gender may predict and cause girls' lower participation in computer science and engineering classes and activities. These stereotypes are endorsed by children in the United States from diverse socioeconomic backgrounds, across multiple racial/ethnic and gender intersections, and by children as young as age six. These stereotypes are also endorsed more strongly than more commonly studied stereotypes that girls have lower abilities than boys. Initial choices to forsake STEM may compound over time and develop into larger disparities in course enrollment, choice of major, and choice of career (34–36). Addressing these societal gender-interest stereotypes before they take root in the minds of young children may help remedy disparities and improve educational equity.

Materials and Methods

The University of Washington Institutional Review Board approved all procedures for Studies 1 through 4. All children and adolescents provided informed assent before participating, and 18-y-olds in Study 2 provided informed consent. Parents were sent opt-out information letters for Studies 1 and 2, signed consent forms for Study 3, and provided verbal consent for Study 4 through online video software. Data and codebooks for all studies are available (37).

Study 1. Study 1 investigated gender-interest stereotypes about computer science among 733 children in grades 3 through 7 in four schools in two suburban school districts in Rhode Island. All schools in Studies 1 and 2 had required programs for all students to participate in computer science. Given work showing greater gender disparities when formal STEM education is absent (9, 38), effects in schools that do not have mandatory computer science education may be even greater than those observed in this sample of schools.

Gender-interest stereotypes favoring boys in computer science were assessed by measuring beliefs about boys' interest ("How much do most boys

like computer science?") versus girls' interest ("How much do most girls like computer science?") and creating a difference score (39, 40), with positive scores indicating a belief that boys are more interested than girls. This type of measure reduces participants' attention to direct group comparisons and allows participants to report no stereotypes by selecting the same response when asked about boys and girls. The questions referred to computer science using terminology (e.g., "coding") developed in partnership with the school district and familiar to students at each school.

Study 2. Students ($N = 1,544$) in grades 1 through 12 in six schools in Rhode Island participated during school on classroom computers. Student's answered questions about both computer science and engineering (counterbalanced). The questions used terminology developed in partnership with the school district (e.g., "computer coding" for computer science). Definitions of each were also included in the survey (e.g., "computer coding means to write instructions for a computer, robot, tablet, or phone app" and "engineering means to design and create large structures [such as roads and bridges] or new products or systems using scientific methods").

Study 3. A total of 50 8-y-old girls (68% White, 28% multiracial, and 4% Asian) learned from a researcher about two novel activities that they could do. Children participated in person in a laboratory. The descriptions of the activities were identical, except a gender-interest stereotype was randomly assigned to be present (stereotyped activity, "girls are much less interested in this activity than boys") or absent (nonstereotyped activity, "girls and boys are equally interested in this activity"). Children learned about the two activities (called "the triangle activity" and "the rectangle activity") in counterbalanced order. The activities were presented in orange folders with a triangle or rectangle shape on the cover and the label "Activity." Whether the stereotyped activity was presented first or second and whether it was called the triangle or rectangle activity were randomly assigned and counterbalanced across participants. We controlled for a gender-ability stereotype (by stating that girls and boys "do equally well on both of these activities") to assess for unique effects of the gender-interest stereotype and counterbalanced the order and labels of the activities. Girls heard descriptions of both activities before reporting their own interest in each using the following two questions (with variants shown in brackets): "How much would you [not] like to do the [triangle/rectangle] activity?" on a scale from 1 (Really not like to) to 6 (Really like to) and "How [interested are you/much are you not interested] in the [triangle/rectangle] activity?" on a scale from 1 (Really not interested) to 6 (Really interested). Finally, they were asked which activity they chose to take home. Consistent with best practices for research with children, the question stems reminded participants of which randomly assigned description was attached to each activity: "Which one would you like to take, the [triangle/rectangle] activity that girls and boys are equally interested in or the [rectangle/triangle] activity that girls are much less interested in than boys?" (refer to *SI Appendix, Dataset S3 Codebook* for exact item and response wording). Participants did not see the contents of the activity folders until their study session was complete. Both activity folders contained parallel age-appropriate genetics activities about monsters or aliens adapted from a "Monster Genetics" activity by SSSTeaching. Afterward, children were debriefed and informed that there were no gender differences for either activity. The rationale for the study was explained to them.

Study 4. Participants were 122 children 8 to 9 y of age (49% girls, 51% boys; 75% White, 22% multiracial, 2% not reported, and 1% Asian) who learned about two computer science activities (counterbalanced between computer "reducing activity" versus computer "searching activity"). Children participated in the experimental procedures at home using Zoom or Google Meet video software synchronously with a researcher. Activity descriptions were identical except for the random assignment of a gender-interest stereotype as present (stereotyped) or absent (nonstereotyped) using the procedure described in Study 3. We again controlled gender-ability stereotypes. The experimenter held up the two folders with labels that were clearly visible on the screen. Both activities were presented in manila folders with the label "Reducing Activity" or "Searching Activity." Whether the stereotyped activity was presented first or second and whether it was called the reducing or searching activity were randomly assigned and counterbalanced across participants. Participants did not see folder contents until their study session was complete. Folders contained age-appropriate computer science activities from <https://www.csunplugged.org> that involved reducing the size of pictures or binary searching. Afterward, children were extensively debriefed and the rationale for the study was explained to them (*SI Appendix*).

Data Availability. Anonymized data have been deposited in the Open Science Framework (37) (<https://osf.io/ve6n9>). All study data are included in the article and/or supporting information.

ACKNOWLEDGMENTS. We thank participating students and school staff; S. Bakos, L. Banham, J. Birkenstock, C. Blondefield, V. Chavez, J. Chen, A. Cimpian, H. Clark, M. Dizon, K. Donohue, E. Farrant, B. Hanson, D. Harpel Forsythe, D. Hathaway, P. Jones, C. Maddox, G. Mak, J. Mendoza, J. Nguyen, L. Ramos, S. Rose, E. Sameth, C. Shieh, E. Stier, M. Tennison, H. Walsh, J. Xie, and O. Yan; and members of the Stereotypes, Identity, and Belonging

Lab. This research was supported by the NSF (Grants 1849902 and 1919218), the Institute of Education Sciences, US Department of Education (Grants R305A180167 to the University of Washington and R305A200520 to the University of Houston), and the Bezos Family Foundation. The opinions expressed are those of the authors and do not represent views of the Institute of Education Sciences, the US Department of Education, or other funders.

- G. L. Cohen, J. Garcia, N. Apfel, A. Master, Reducing the racial achievement gap: A social-psychological intervention. *Science* **313**, 1307–1310 (2006).
- C. M. Steele, S. J. Spencer, J. Aronson, Contending with group image: The psychology of stereotype and social identity threat. *Adv. Exp. Soc. Psychol.* **34**, 379–440 (2002).
- L. Bian, S.-J. Leslie, A. Cimpian, Gender stereotypes about intellectual ability emerge early and influence children's interests. *Science* **355**, 389–391 (2017).
- S. Cheryan, A. Master, A. N. Meltzoff, Cultural stereotypes as gatekeepers: Increasing girls' interest in computer science and engineering by diversifying stereotypes. *Front. Psychol.* **6**, 49 (2015).
- A. A. Farinde, C. W. Lewis, The underrepresentation of African American female students in STEM fields: Implications for classroom teachers. *US-China Edu. Rev. Bus.* **4**, 421–430 (2012).
- S.-J. Leslie, A. Cimpian, M. Meyer, E. Freeland, Expectations of brilliance underlie gender distributions across academic disciplines. *Science* **347**, 262–265 (2015).
- A. Master, A. N. Meltzoff, Cultural stereotypes and sense of belonging contribute to gender gaps in STEM. *Int. J. Gen. Sci. Technol.* **12**, 152–198 (2020).
- S. J. Spencer, C. Logel, P. G. Davies, Stereotype threat. *Annu. Rev. Psychol.* **67**, 415–437 (2016).
- S. Cheryan, S. A. Ziegler, A. K. Montoya, L. Jiang, Why are some STEM fields more gender balanced than others? *Psychol. Bull.* **143**, 1–35 (2017).
- J. R. Cimpian, T. H. Kim, Z. T. McDermott, Understanding persistent gender gaps in STEM. *Science* **368**, 1317–1319 (2020).
- NSF, "Women, minorities, and persons with disabilities in science and engineering." <https://ncses.nsf.gov/pubs/nsf19304/data/>. Accessed 4 May 2021.
- C. Criado Perez, *Invisible Women: Data Bias in A World Designed for Men* (Abrams Press, 2019).
- A. Levanon, P. England, P. Allison, Occupational feminization and pay: Assessing causal dynamics using 1950–2000 U.S. census data. *Soc. Forces* **88**, 865–891 (2009).
- K. McElrath, "Schooling during the COVID-19 pandemic." <https://www.census.gov/library/stories/2020/08/schooling-during-the-covid-19-pandemic.html>. Accessed 9 July 2021.
- A. Master, S. Cheryan, A. Moscatelli, A. N. Meltzoff, Programming experience promotes higher STEM motivation among first-grade girls. *J. Exp. Child Psychol.* **160**, 92–106 (2017).
- L. S. Liben, R. S. Bigler, The developmental course of gender differentiation: Conceptualizing, measuring, and evaluating constructs and pathways. *Monogr. Soc. Res. Child Dev.* **67**, i–viii, 1–147, discussion 148–183 (2002).
- C. L. Martin, L. Eisenbud, H. Rose, Children's gender-based reasoning about toys. *Child Dev.* **66**, 1453–1471 (1995).
- S. Cheryan, V. C. Plaut, P. G. Davies, C. M. Steele, Ambient belonging: How stereotypical cues impact gender participation in computer science. *J. Pers. Soc. Psychol.* **97**, 1045–1060 (2009).
- T. C. Denney, N. Dasgupta, Female peer mentors early in college increase women's positive academic experiences and retention in engineering. *Proc. Natl. Acad. Sci. U.S.A.* **114**, 5964–5969 (2017).
- A. Master, S. Cheryan, A. N. Meltzoff, Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *J. Educ. Psychol.* **108**, 424–437 (2016).
- G. M. Walton, G. L. Cohen, A question of belonging: Race, social fit, and achievement. *J. Pers. Soc. Psychol.* **92**, 82–96 (2007).
- D. D. Tobin et al., The intrapsychics of gender: A model of self-socialization. *Psychol. Rev.* **117**, 601–622 (2010).
- M. T. Wang, Educational and career interests in math: A longitudinal examination of the links between classroom environment, motivational beliefs, and interests. *Dev. Psychol.* **48**, 1643–1657 (2012).
- C. Riegle-Crumb, B. King, E. Grodsky, C. Muller, The more things change, the more they stay the same? Prior achievement fails to explain gender inequality in entry into STEM college majors over time. *Am. Educ. Res. J.* **49**, 1048–1073 (2012).
- R. F. Baumeister, M. R. Leary, The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychol. Bull.* **117**, 497–529 (1995).
- A. N. Meltzoff, "Origins of social cognition: Bidirectional self-other mapping and the 'Like-Me' hypothesis" in *Navigating the Social World: What Infants, Children, and Other Species Can Teach Us*, M. R. Banaji, S. A. Gelman, Eds. (Oxford University Press, 2013), pp. 139–144.
- A. Master, Gender stereotypes influence children's science, technology, engineering, and math motivation. *Child Dev. Perspect.* **15**, 203–210 (2021).
- S. E. Gaither, J. D. Remedios, J. R. Schultz, S. R. Sommers, Priming White identity elicits stereotype boost for biracial Black-White individuals. *Gr. Proc. & Int. Rel.* **18**, 778–787 (2015).
- H. A. Vuletich, B. Kurtz-Costes, E. Cooley, B. K. Payne, Math and language gender stereotypes: Age and gender differences in implicit biases and explicit beliefs. *PLoS One* **15**, e0238230 (2020).
- N. Ellemers, Gender stereotypes. *Annu. Rev. Psychol.* **69**, 275–298 (2018).
- A. M. Koenig, A. H. Eagly, Evidence for the social role theory of stereotype content: Observations of groups' roles shape stereotypes. *J. Pers. Soc. Psychol.* **107**, 371–392 (2014).
- S. T. Fiske, "Stereotyping, prejudice, and discrimination" in *The Handbook of Social Psychology*, D. T. Gilbert, S. T. Fiske, G. Lindzey, Eds. (McGraw-Hill, ed. 4, 1998), pp. 357–411.
- S. Cheryan et al., Double isolation: Identity expression threat predicts greater gender disparities in computer science. *Self. Ident.* **19**, 412–434 (2020).
- S. J. Ceci, W. M. Williams, S. M. Barnett, Women's underrepresentation in science: Sociocultural and biological considerations. *Psychol. Bull.* **135**, 218–261 (2009).
- I. H. Settles, Women in STEM: Challenges and determinants of success and well-being. *Psychol. Sci. Agen.* <https://www.apa.org/science/about/psa/2014/10/women-stem>. Accessed 6 July 2021.
- V. Valian, *Why So Slow? The Advancement of Women* (MIT Press, 1998).
- A. Master, A. N. Meltzoff, S. Cheryan, Gender stereotypes about interests start early and cause gender disparities in computer science and engineering. *Open Science Framework* (2021). <https://osf.io/ve6n9/>. Deposited 25 October 2021.
- M. Federman, State graduation requirements, high school course taking, and choosing a technical college major. *B.E. J. Econ. Anal. Policy* **7**, 4 (2007).
- M. Burnett, B. Kurtz-Costes, H. A. Vuletich, S. J. Rowley, The development of academic and nonacademic race stereotypes in African American adolescents. *Dev. Psychol.* **56**, 1750–1759 (2020).
- D. Cvencek, M. Kapur, A. N. Meltzoff, Math achievement, stereotypes, and math self-concepts among elementary-school students in Singapore. *Learn. Instr.* **39**, 1–10 (2015).