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# Girls' comparative advantage in language arts explains little of the gender gap in math-related fields: A replication and extension

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**Women remain underrepresented in most math-intensive fields. [Breda and Napp, *Proc. Natl. Acad. Sci. U.S.A.* 116, 15435 (2019)] reported that girls' comparative advantage in reading over math (i.e., the intraindividual differences between girls' reading vs. math performance, compared to such differences for boys) could explain up to 80% of the gender gap in students' intentions to pursue math-intensive studies and careers, in conflict with findings from previous research. We conducted a conceptual replication and expanded upon Breda and Napp's study by using new global data (PISA2018, *N* = 466,165) and a recent US nationally representative longitudinal study (High School Longitudinal Study of 2009, *N* = 6,560). We coded students' *intended* majors and careers and their *actual* college majors. The difference between a student's math vs. reading performance explained only small proportions of the gender gap in students' intentions to pursue math-intensive fields (0.4 to 10.2%) and in their enrollment in math-intensive college majors (12.3%). Consistent with previous studies, our findings suggest girls' comparative advantage in reading explains *a minority* of the gender gap in math-related majors and occupational intentions and choices. Potential reasons for differences in the estimated effect sizes include differences in the operationalization of math-related choices, the operationalization of math and reading performance, and possibly the timing of measuring intentions and choices. Therefore, it seems premature to conclude that girls' comparative advantage in reading, rather than the cumulative effects of other structural and/or psychological factors, can largely explain the persistent gender gap in math-intensive educational and career choices.**

gender gap | math-intensive fields | career choice | STEM diversity

Why do women remain underrepresented in math-intensive fields, such as physics, computer science, and engineering, despite continuous (inter)national efforts to reduce these gender disparities? One key contributing factor proposed in the literature is that women tend to be comparatively stronger at reading than math, so they pursue educational and career paths in which they hold relative strengths (i.e., in the verbal domain). Evidence from 67 countries participating in the 2015 Program for International Student Assessment (PISA2015) suggests that although girls outperform boys in math in *some* countries, girls—compared to boys—have a larger intraindividual strength in reading over math in *all* 67 countries (1).

Can such nearly universal gender differences in relative academic strengths explain the majority of the persistent underrepresentation of women in math-intensive fields? While early studies did not support this idea (2, 3), more recently, Breda and Napp (4) reported that girls' comparative advantage in reading could explain up to 80% of the gender gap in students' intentions to pursue math-intensive studies and careers, and up to 49% of high-school students' intentions and actual enrollment in a science track at the end of high school. Understanding the generalizability of this finding and reconciling it with previous results is important for theoretical and practical reasons. As Breda and Napp's main finding suggests, suppose women's underrepresentation in math-intensive fields is mainly driven by their comparative advantage in reading over math. In that case, efforts to reduce systematic barriers to women's entry into math-intensive fields might be ineffective unless they also reduce the comparative math-reading (MR) performance gaps.

We aim to conceptually replicate and expand upon Breda and Napp's research by using two recent large datasets (Table 1) and exploring the potential implications of the MR gender gap for actual college major selection. First, we use a newer wave of the same data: Breda and Napp (4) used data from PISA2012, including 301,360 age-15 students from 64 countries/districts; we use data from PISA2018, including 466,165 age-15 students from 77 countries/districts. Notably, PISA2018 differed from PISA2012 in operationalizing the key outcome variable (i.e., study/career intentions). In PISA2012, students responded to five forced-choice format items inquiring about their intentions to use mathematics

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**Table 1. Studies examining to what extent intraindividual MR performance differences explain the gender gap in math-intensive educational and career intentions and choices**

| Article | Sample | Math/reading performance measure | Outcome measure | Share of the gender gap in outcome explained by MR |
|---|---|---|---|---|
| Jonsson (2) | 51,158 Swedish students born in 1972 to 1976 who chose academic study programs (Gymnasium) for upper secondary school | Teacher-assigned school marks in Grade 9 | Program choices at the upper secondary level (natural science/technics/engineering vs. other) in Grade 10 | 10 to 30% |
| Riegle-Crumb et al. (3) | US high school class of 1982/1992/2004 (*N* = 3,290/3,791/4,905); enrolled in 4-y colleges; nationally representative | Test scores in Grades 10 and 12; high school GPAs | College majors (physical science/ engineering vs. other) | Test score: "very small" (exact number not reported); grades: 11 to 14% |
| Dekhtyar et al. (6) | 167,776 Swedish people born in 1977 to 1979 who proceeded beyond compulsory education; with data in later choices | Teacher-assigned school marks in Grade 9 | An index of verbal vs. numerical demands for different fields of education or occupation | 15% for educational fields; 11% for occupational choices |
| Sadowski et al. (7) | 233,864 Polish students who took matriculation exams in 2018 | Scores in standard matura exams at age 19 | Whether the student chose to take the extended exam in math/physics/ computer sciences at age 19 | "a small portion" (9.4% based on our calculation) |
| Stearns et al. (8) | 16,710 US students who are 2004 high school graduates and took at least one STEM college course | First-year GPAs in STEM and non-STEM | College majors (physical science/ engineering vs. other) | "not contribute to" (exact number not reported) |
| Aucejo and James (9) | 500,000 students in England who finished compulsory education in 2006/2007 | Latent scores ages 15 to 16 | STEM fields enrollment in college | 25% (conditional on college enrollment) |
| Breda and Napp (4) | 301,360 age-15 students from 64 countries/ districts (PISA2012) | PISA math and reading test scores | An index built from 5 forced-choice questions* | 78.4% |
| Breda and Napp (4), French data | 11,659 French high school students from the Paris region from a STEM intervention study (the L'Oréal study) | Grade 10 national exam scores; Grade 10 class grades | Intention for scientific track in Grade 11; enrollment in a scientific track in Grade 11; intention to study science later | Exam score/grade: 46%/56% for Grade 11 intention; 49%/55% for enrollment in Grade 11; 29%/37% for intention to pursue science in the future |
| Our replication 1 | 466,165 age-15 students from 77 countries/ districts (PISA2018) | PISA math and reading test scores | Expected career at age 30 (math-intensive vs. other) | 0.4% |
| Our replication 2 | US high school class of 2009 (*N* = 6,560); all enrolled in 4-y colleges; nationally representative (HSLS:09) | SAT math and reading test scores; high-school grades | Intended majors before college; majors 3 y after high school (math-intensive vs. other) | SAT/grade: 10.2%/6.1% for intention; 12.3%/6.9% for actual choices |

*Note:* For HSLS:09, *N* is rounded to the nearest ten per the Institute for Education Sciences restricted-use data procedures guidelines.
*An example: "For each pair of statements, please choose the item that best describes you: a. I intend to take additional mathematics courses after school finishes; b. I intend to take additional <test language> courses after school finishes."

rather than language or science in their future studies and careers. In PISA2018, students responded to an open-ended question about their intended field/career when they turned 30. We grouped students' open-ended responses into "math-intensive fields" and "others." The math-intensive fields category included computer science, engineering, physical science, mathematics, and statistics. These fields require advanced math knowledge and skills and show persistent gender disparities (5). We performed robustness checks with alternative categorizations. Second, we re-estimate differences in math-intensive career choices by using students' *actual* majors in college instead of *intended* majors reported during high school. We used data from the US Department of Education's High School Longitudinal Study of 2009 (HSLS:09). Ninth-graders were recruited in 2009 and followed for 7 y. Students reported their *intended* college majors in 2013, when most had graduated high school, and their *actual* majors 3 y later. We coded students' intended and actual majors as math-intensive vs. other.

## Results

Our analyses replicate Breda and Napp's (4) results that girls have a comparative advantage in reading, but our estimated effect sizes are smaller (using the same analytical approach). The gender gap in MR performance differences (Dataset S1, Column 3) is about 49% of a *SD*. We find a similar pattern regarding MR performance differences in the HSLS:09 data (35% of a *SD*).

The gender gap in math-related career intentions amounts to 16% of a *SD* worldwide [Dataset S1, Column 4; this number is 22% in Breda and Napp (4)] and varies across countries. Gender differences in MR performance cannot explain the gender gap in intentions. Breda and Napp (4) found that controlling for individual-level MR performance differences made the gender gap in intentions disappear almost entirely (Dataset S1, Column 8), but we failed to find the same pattern (Fig. 1). MR explains only 0.4% of the gender gap in career intentions worldwide (Dataset S1, Column 7). The corresponding estimates ranged from –4.8% (in the Netherlands) to 11.9% (in Morocco) and were –2.8% in the United States. For details, see ref. 10.

We obtained similar results using the HSLS:09 data. In HSLS:09, the gender gap is 22% of a *SD* for math-related college major intentions and 19% of a *SD* for actual enrollment. Controlling for MR performance differences explained 10.2% of the gender gap in math-related college-major intentions and reduced the gender gap in actual enrollment by 12.3% (Fig. 1). All reported results are consistent across different categorizations of math-intensive fields (10). In HSLS:09, we found similar results when: replacing math and reading SAT scores with high school math and English grade point averages (GPAs) as performance measures; dropping the sample restriction of students having enrolled in college; and focusing on students' high-school course choices instead of college-major choices as an outcome (i.e., students' enrollment in math-intensive high-school courses; *SI Appendix*).

## Discussion

Our results suggest that girls' comparative advantage in reading over math explains only a small proportion of the gender gap in math-ntensive educational and career choices. This finding contradicts Breda and Napp's (4) main result but is consistent with prior evidence (refs. 2, 3, and 6–9 in Table 1). Several factors may contribute to differences in the estimated effect sizes. First, heterogeneous findings may result from different operationalizations of educational and career intentions and choices. Breda and Napp (4) used forced-choice questions that asked students to choose between math and language arts/science in PISA2012. Using auxiliary data from an intervention study conducted in France, they also measured 10th graders' intentions to enroll in a scientific track in Grade 11, actual enrollment in a scientific track in Grade 11, and intentions to study

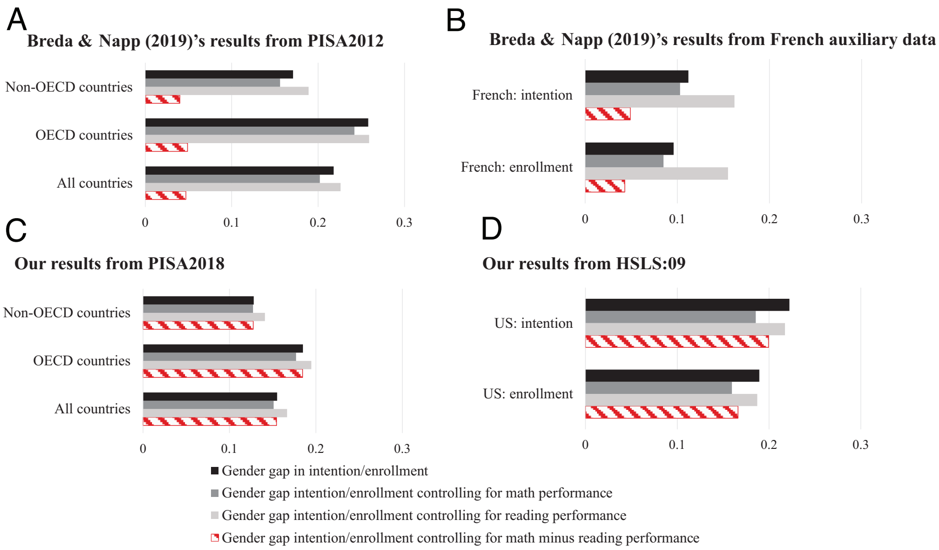


**Fig. 1.** Unconditional and conditional gender gaps (boys minus girls) in intentions to pursue math-intensive tracks/careers or actual enrollment in math-intensive tracks/college majors. Panels (*A* and *B*). PISA2012 and French data reported from Breda and Napp (4) (data retrieved from their tables S1b and S6). In Panel *B*: intention and enrollment are for choosing a scientific track at Grade 11; performance is national exam scores. Panels (*C* and *D*). PISA2018 and HSLS:09. In Panel (*D*): intention and enrollment are for choosing a math-related major at college; performance is SAT scores. *Note:* OECD: The Organisation for Economic Co-operation and Development.

science after high school. By comparison, we examined the college majors and career choices students named in an open-ended format and their actual college majors later on in HSLS:09 as well as age-30 career expectations in PISA2018. In supplemental analyses, we also examined students' math-related high school course enrollment in HSLS:09. Notably, our measures are similar to those in previous studies that did not find a large MR effect on the gender gap in math-related career/major choices and course selection (10 to 30%, Table 1). It is possible that in situations where students are forced to choose either math or language arts, the MR performance gap explains a larger proportion of variance in gendered educational and career choices. However, the MR performance gap does not seem to be the primary driver of math-related course selection, college-major selection, and career intentions.

Second, different math and language arts performance measures may affect estimates of MR differences due to self-selection (e.g., high-achieving students choosing to take a college entrance exam such as the SAT) and potentially biased grading practices. Breda and Napp's (4) French study used national exam scores and class grades for math and French, while we used SAT math and reading scores and high school math and English GPAs in HSLS:09. However, previous studies consistent with our findings have used a range of performance measures (Table 1), so this is not likely to be a major contributor to the observed differences.

Third, different time points for measuring math-related intentions and choices may affect the explanatory power of gender-specific MR differences, which may be most relevant for proximal choices in high school (e.g., course or academic track selection) and less relevant for more distal choices (e.g., college majors). However, while students' relative MR strengths could contribute to gendered educational and career choices (11), our review of previous evidence (Table 1) and our analyses of PISA2018 and HSLS:09 data suggest that the MR gender gap explains a relatively *small* proportion of the gender gap in science, technology, engineering, and mathematics (STEM) choices across different countries, measures, and outcomes. We believe the discrepant operationalizations of math-related intentions and choices used in different studies to be the most likely reason for discrepant findings. Using a broader set of measures of STEM career pursuit and conducting comparative analyses across different measures is a worthwhile avenue for future research.

## Materials and Methods

**Data and Key Variables.** We analyze data from PISA2018 and HSLS:09. The key variables for PISA2018 are students' math and reading scores and their response to "What kind of job do you expect to have when you are about 30 y old?". Only students with available information on these variables were included (466,165 age-15 students from 77 countries/districts). The key variables for HSLS:09 are students' math and reading SAT scores, open-ended responses about college-major intentions, and later self-reported major/field of study in college. Only respondents with valid sample weights, enrolled in a 4-y institution, and with available data on SAT scores and college majors were included ($N$ = 6,560). See *SI Appendix* for all variables and additional analyses.

**Data Analysis.** We use the same analytical approach as Breda and Napp (4; *SI Appendix*).

**Data, Materials, and Software Availability.** Analyses for HSLS:09 require a restricted-use dataset from the US Department of Education. Other materials are available at https://osf.io/wveam/ (10).

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