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ORIGINAL ARTICLE

Parents' Beliefs about High School Students' Spatial Abilities: Gender Differences and Associations with Parent Encouragement to Pursue a STEM Career and Students' STEM Career Intentions

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Abstract
In the present study, we investigated whether parents' beliefs about their high school aged adolescents' spatial abilities (i.e., spatial visualization, mental manipulation, and navigation abilities) differed based on their child's gender. We also examined whether these beliefs related to parents' encouragement of their child to pursue a Science, Technology, Engineering, or Mathematics (STEM) career as well as students' actual STEM major and career intentions. Data were collected from 117 pairs of U.S. high school students and one of their parents. We found that parents of young men thought their child had higher mental manipulation and navigation abilities than did parents of young women, even after statistically controlling for adolescents' actual spatial abilities. Parents who perceived that their child had higher mental manipulation ability were more likely to encourage their child to pursue a STEM career, and those students were more likely to report that they intended to pursue a STEM career. These findings suggest that parents' beliefs about how good their child is at spatial tasks may be based more strongly on gender stereotypes than on their child's actual spatial abilities. Helping to make parents aware of these beliefs could be a potential lever of intervention to increase women's participation in STEM careers.

Keywords Motivation · Parental attitudes · Parental expectations · Human sex differences · STEM · Attitudes · Occupational aspirations

Researchers, policymakers, and practitioners in the United States have become increasingly concerned with promoting students' interest and participation in Science, Technology, Engineering, and Mathematics (STEM) fields (National Research Council 2014). High school is a particularly important time as students are beginning to decide whether they intend to choose a STEM major or pursue a STEM career. Indeed, researchers have found that students' STEM career

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intentions in high school are strong predictors of actual STEM undergraduate degree attainment (Maltese and Tai 2011; Wang 2013). Thus, it is critical to better understand what factors influence students' decisions to pursue a STEM career during their high school years.

Expectancy-value theorists posit that students' choices such as whether to pursue a STEM career are influenced by students' own self-beliefs and values as well as by the beliefs of important socializers such as parents (Wigfield and Eccles 2000). According to the parent socialization model embedded within expectancy-value theory (Eccles et al. 1993a, b), parents' beliefs about their children's abilities, which are communicated via parents' behaviors and practices, shape students' academic choices. In support of this model, researchers have found that parents' beliefs about their children's abilities, as well as their behaviors and practices, predict students' intentions to pursue a STEM career and persistence in STEM careers (Chhin et al. 2008; Ing 2014; Sonnert 2009).

Previous research on parents' beliefs and students' STEM outcomes has mostly focused on parents' beliefs about their children's math abilities. There are relatively few studies of parents' beliefs about other types of abilities that are critical to STEM success, such as parents' beliefs about their children's spatial abilities. Although spatial abilities, such as spatial visualization (i.e., the ability to visualize details in one's mind), mental manipulation (i.e., the ability to mentally "transform" an object), and navigation (i.e., the ability to successfully move through one's environment) are critical for success in STEM fields (Wai et al. 2009), no studies to our knowledge have examined how parents' beliefs about their children's spatial abilities predict parents' behaviors and students' STEM outcomes. Parents' beliefs about their children's spatial abilities might uniquely predict the extent to which they may participate in spatial activities with their children or encourage their children to participate in spatial activities. Thus, these beliefs may predict variance in parents' behavior and students' STEM outcomes even after taking into account parents' beliefs about their child's math ability.

Further, research suggests that parents' beliefs about their children's abilities are influenced by gender stereotypes. In math, parents tend to believe that males have higher ability than females (Furnham et al. 2002; Parsons et al. 1982; Tiedemann 2000; Yee and Eccles 1988). There is also evidence that there are similar patterns in parents' beliefs about their children's spatial abilities (Furnham 2000; Furnham et al. 2002). These gendered beliefs could lead parents to treat young men and women differently, which may contribute to the persistent gender gap in certain STEM fields including physical science, computer science, and engineering (National Science Board 2015).

The aims of the present study are to: (a) examine whether parents hold gendered beliefs about their high school-aged children's spatial abilities, (b) examine how parents' beliefs about their children's spatial abilities are associated with parents' behavior (i.e., encouragement of their child to pursue a STEM career) independent of parents' beliefs about their child's math ability; and (c) test whether parents' behavior (i.e., encouragement of their child to pursue a STEM career) mediates the association between parents' beliefs about their children's spatial abilities and students' intentions to pursue a STEM career or major in a STEM field. Our work will extend the parent socialization model into a new domain (spatial ability) and shed light on how parents' beliefs about spatial ability relate to students' academic choices in STEM.

The Critical Role of Spatial Abilities in STEM

Decades of research in STEM education have identified a positive relation between spatial abilities and student achievement in STEM domains (Lubinski 2010; Wai et al. 2009). Spatial abilities—including mental manipulation, visualization, and navigation—have been related to achievement in a wide variety of tasks across STEM domains and for students from preschool through adulthood. For instance, spatial abilities predict linear number line knowledge (Gunderson et al. 2012), organic chemistry problem solving (Stieff et al. 2014), biology and anatomy concept understanding (Zhang et al. 2017), and comprehension from science texts (Fiorella and Mayer 2017). In addition to specific task performance, spatial abilities predict the likelihood that students will major in STEM, pursue advanced STEM education, and persist in a STEM career (Wai et al. 2009; Yoon and Mann 2017).

One explanation for the relation between spatial ability and STEM achievement is that tasks in STEM domains have high visual-spatial demands (National Research Council 2006; Newcombe et al. 2015). For example, understanding why the Earth has seasons requires visualizing the tilt of the Earth's axis at various points in its orbit relative to the sun. Similarly, many STEM fields involve visualizing two-dimensional images (e.g., anatomical scans, molecular diagrams, geological maps) as three-dimensional shapes or imagining the two-dimensional cross sections of three-dimensional shapes (e.g., engineering diagrams). Many tasks in mathematics also benefit from spatial imagery, such as the mental visualization of number lines (e.g., comparing relative magnitude), or the ability to visualize concepts (e.g., derivatives, standard deviation). Some researchers have argued that due to the spatial demands of STEM tasks, spatial ability serves as a prerequisite for success in STEM fields (Newcombe 2016; Uttal and Cohen 2012). Further, there is growing evidence that enhancing spatial ability may be one way to increase participation in STEM majors and careers (Miller and Halpern 2013; Newcombe 2016; Uttal et al. 2013).

Eccles' Parent Socialization Model

Expectancy-value theorists such as Eccles and Wigfield (Eccles Parsons et al. 1983; Wigfield and Eccles 2000) have proposed and demonstrated that students' own expectancies (e.g., Can I do this?) and values (e.g., Do I want to do this?) influence their academic achievement and choices. They have also demonstrated the important role of socialization in the development of students' expectancies and values over time, particularly by parents (for an overview, see Lazarides et al. 2015). The parent socialization model within expectancy-value theory (Eccles et al. 1993a, b) posits that parents' beliefs *about* their children, such as their beliefs about ability (e.g., How good is your child at math?) and values (e.g., How important is math for your child?) for their children, influence their behaviors and practices, which then influence students' own expectancies, values, achievement, and choices. Decades of research utilizing both longitudinal and cross-sectional designs have demonstrated support for these pathways (e.g., Eccles 2007; Eccles et al. 1993a, b).

For example, Simpkins et al. (2012) found, over a 12-year period, that parents' beliefs about their children's math ability predicted parents' behaviors (e.g., modeling, encouragement, provision of materials in the home, coactivity), controlling for their child's actual ability. These behaviors predicted students' own self-beliefs about ability and values in math, which in turn predicted their academic choices such as number of math courses taken in high school. Researchers have extended this work to later STEM outcomes; for example, Harackiewicz et al. (2012) found that an intervention that increased parents' value of STEM courses for high school students led to students enrolling in more STEM courses 2 years later. Greater high school STEM preparation, in turn, was associated with STEM career pursuit 5 years later (Rozek et al. 2017). As a whole, this work suggests that parents' beliefs about their children's abilities and values in mathematics and science are important influences on students' later STEM outcomes.

In the present study, we extend the parent socialization model to the spatial domain and focus specifically on parents' beliefs *about* their children's spatial abilities. Although spatial and math abilities are positively correlated (Casey et al. 1997; Gunderson et al. 2012; Newcombe et al. 2015; Tosto et al. 2014), studies suggest that they are distinct abilities and predict unique variance in educational and vocational outcomes (e.g., Shea et al. 2001). Thus, parents' beliefs about their child's spatial abilities may uniquely predict parents' behaviors and practices, such as their encouragement of their child to pursue a STEM career, as well as students' actual STEM career intentions.

Gender Differences in Parents' Beliefs

Women remain underrepresented in certain STEM fields, including physical sciences, computer science, and engineering (National Science Board 2015). Although there are many potential reasons for these differences (see Dasgupta and Stout 2014), decades of research suggest that parent socialization plays a critical role (Gunderson et al. 2012). Researchers have consistently demonstrated that gender stereotypes influence parents' beliefs about their children's math ability, such that parents of males tend to perceive their child as being better at math than parents of females (Furnham et al. 2002; Parsons et al. 1982; Tiedemann 2000; Yee and Eccles 1988; see Gunderson et al. 2012, for a review). These differences hold even when controlling for actual math ability (see Hyde 2014, for review), and they have been found to predict parents' career expectations for their children, parents' behaviors toward their children, and students' career decisions years later (Chhin et al. 2008). However, fewer studies have examined gender differences in parents' beliefs about their children's spatial abilities. In one of the only studies to examine this, Furnham and colleagues (Furnham et al. 2002) found that parents of males estimated that their child had higher spatial intelligence ("the ability to find your way around the environment and to form mental images"; p. 29) than parents of females.

Despite the fact that few studies have examined children's spatial abilities explicitly, there is reason to believe that parents would hold gendered beliefs about them. Gender stereotypes about spatial ability—specifically that men are better at mental manipulation or rotation tasks than women and that these abilities are more "masculine"—have been extensively documented (Halpern et al. 2011; Reilly and Neumann 2013). This stereotype is not unfounded because gender differences in actual spatial ability (favoring men) have persisted, particularly on timed spatial tasks involving mental rotation (Jansen et al. 2013; for reviews see: Hyde 2016; Levine et al. 2016; Maeda and Yoon 2013; Voyer et al. 2017). Critically, in samples of college and college-bound students, differences in mental rotation skill have been found to mediate the relation between gender and STEM outcomes such as STEM major choice (Yoon and Mann 2017) and math SAT score (Casey et al. 1997). Further, a recent set of meta-analyses by Syzmanowicz and Furnham (2011) found that men give consistently higher self-estimates of their spatial ability than women (also see Furnham and Thomas 2004; Szymanowicz and Furnham 2013).

The Present Study

In the present study, we investigate three research questions. First, we examine whether parents' beliefs about their high school-aged child's math and spatial abilities differ based on students' gender (Research Question 1). Given much previous research linking masculinity to spatial ability, we expect to find that parents of young men rate their child as having higher spatial abilities than parents of young women. But, would these differences be based on stereotypes, or would they simply reflect actual differences in young men and women's spatial abilities? In order to test this question explicitly, we control for actual differences in students' academic and spatial abilities.

Second, we examine whether parents' beliefs about their child's spatial abilities are associated with parents' encouragement of their child to pursue a STEM career, even when accounting for other likely influences (i.e., parent beliefs about child math ability, students' actual academic and spatial abilities, parent gender, and parent STEM occupation) (Research Question 2). We expect to find that parents' beliefs about spatial ability uniquely predict their behavior (i.e., encouragement), even when controlling for students' actual abilities and parents' beliefs about their child's math ability.

Third, in an exploratory analysis, we examine whether parents' encouragement of their child to pursue a STEM career mediates the relation between parents' beliefs about their child's spatial abilities and high school students' intentions to major in STEM and pursue a STEM career (Research Question 3). These tests will allow us to explore the link between parents' beliefs and behaviors and students' actual STEM career intentions, which are strongly predictive of actual STEM undergraduate degree attainment (Maltese and Tai 2011; Wang 2013). Specifically, we examine students' STEM major intentions as a more proximal outcome and their STEM career intentions as a more distal outcome. In line with prior research (e.g., Goldman and Hewitt 1976) and consistent with well-established findings that mathematics knowledge is an essential component of all STEM fields (Breiner et al. 2012; Moakler Jr and Kim 2014; National Science Board 2015; Watt et al. 2017), we use the extent to which particular majors or careers require math skills as a proxy for how STEM-related these majors or careers are.

Method

Participants

Participants were 117 high school students attending public high schools in the mid-Atlantic region of the United States (M_{age} = 16.66, range = 16–18; 62 female [53%], 54 male [46%], 1 no gender reported [.9%]; 84 White [71.8%], 19 Biracial/Multiracial [16.2%], 5 Hispanic/Latino [4.3%], 4 Asian [3.4%], 3 Black [2.6%], 1 Other [.9%], 1 no race/ethnicity reported [.9%]), and one of their parents (85 female [71.4%], 29 male [24.8%], 3 no gender reported [2.6%%]; 88 White [75.2%], 14 Hispanic/Latino [12%], 5 Asian [4.3%], 4 Black [3.4%], 3 Biracial/Multiracial [2.6%], 2 Other [1.7%], 1 no race/ethnicity reported [.9%]). Participants and their parents were recruited as part of a larger study on science education and the development of spatial thinking, and students attended one of six public high schools (5 suburban, 1 urban). Parents reported their educational attainment: 18 (15.8%) parents did not receive a college degree, 51 (44.7%) received a Bachelor's degree, 35 (30.7%) received a Master's degree, 6 (5.2%) received a Professional degree, 4 (3.4%) received a Doctorate degree, and 3 (2.6%) did not report their educational attainment. Parents also reported their yearly household income: 15 (12.8%) parents reported an income of under $100,000, 40 (34.2%) reported an income between $100,000-200,000, 32 (27.4%) reported an income between $200,000-300,000, 14 (12.0%) reported an income of over $300,000, and 16 parents (13.7%) did not report their income. This study was approved by an institutional review board for compliance with standards for the ethical treatment of human participants, and all participants signed written informed consent forms prior to their participation.

Measures

Parents' Beliefs about their Children's Spatial Abilities

We measured parents' beliefs about their children's spatial abilities using the items from the Spatial Anxiety Scale by Lyons and colleagues (Lyons et al. 2018; see Table 1 for all items). The original scale was developed to measure people's own self-reported anxiety when doing specific spatial tasks, but we modified the scale to assess parents' beliefs about their children's spatial ability. Parents were provided with a list of the 24 spatial tasks from the Spatial Anxiety Scale but instead of reporting anxiety, they were asked to report how skilled their child was at each task on a 7-point scale from 1 (*Not at all good*) to 7 (*Very good*). Eight items asked about *spatial visualization skills* (e.g., "Creating a drawing or painting that reproduces the details of a photograph as precisely as possible"), eight items asked about *mental manipulation skills* (e.g., "Imagining what a 3-dimensional landscape model would look like from a different point of view"), and eight items asked about *navigation skills* (e.g., "Finding his/her way back to his/her hotel after becoming lost in a new city [without a cell phone or GPS]").

Because we modified the target and context of the scale by asking parents to report on their perceived level of their children's abilities (rather than asking individuals to report on their own anxiety with these tasks), we did some development and validation work with the scale before testing our central hypotheses. Prior to data collection, we pilot tested the parent report items with a small sample of six undergraduate students, three graduate students, and two parents. We used

Table 1 Items and loadings for parent beliefs about child spatial abilities scale

Items	Factor 1	Factor 2	Factor 3
Finding his/her way back to his/her hotel after becoming lost in a new city (without a cell phone or GPS)	.814	.194	.189
Doing the navigational planning for a long car trip (without a cell phone or GPS)	.788	.355	.040
Memorizing routes and landmarks on a map	.792	.276	.100
Trying a new route that he/she thinks will be a shortcut, without the benefit of a map (or cell phone/GPS)	.851	.243	.132
Trying to get somewhere he/she has never been to before in the middle of an unfamiliar city (without a cell phone/GPS)	.883	.083	.163
Finding his/her way to an appointment in an area of a city or town with which he/she is not familiar (without a cell phone/GPS)	.869	.158	.197
Finding his/her way back to a familiar area after realizing he/she has made a wrong turn and become lost while driving (without a cell phone/GPS)	.815	.304	.128
Following directions to a location across town without the use of a map (or cell phone/GPS)	.808	.231	.041
Imagining how the orbit of a comet changes over time	.206	.721	.082
Imagining how gravity interacts with a passing light beam	.283	.659	.137
Imagining what a 3-dimensional landscape model would look like from a different point of view	.136	.802	.270
Imagining the motion of a mechanical system given a static picture of the system	.335	.831	−.016
Determining how a series of pulleys will interact given only a 2-dimensional diagram	.230	.879	−.069
Imagining and mentally rotating a 3-dimensional figure	.203	.869	.133
Imagining a 3-dimensional structure of the human brain from a 2-dimensional image	.224	.807	.084
Imagining the 3-dimensional structure of a complex molecule using only a 2-dimensional picture for reference	.215	.828	.096
Re-creating a signature from memory	.141	−.092	.629
Creating a drawing or painting that reproduces the details of a photograph as precisely as possible	−.075	.388	.560
Recalling the exact details of a relative's face whom he/she has not seen in several years	.346	.049	.744
Imagining and describing the appearance of a radio announcer he/she has never actually seen	.048	−.124	.710
Giving a detailed description of a person's face whom he/she has only met once	.286	.057	.814
Recalling the shade and pattern of a person's tie he/she met for the first time the previous evening	.056	.143	.658
Describing in detail the cover of a book to a bookseller because he/she has forgotten both the title and author of the book	.020	.211	.699
A test in which he/she is allowed to look at and memorize a picture for a few minutes, and then is given a new, similar picture and asked to point out any differences between the two pictures	.093	.403	.607

Varimax rotation. Fixed number of factors to three. The three segments of the table cluster each of the three factors in order wherein navigation items loaded onto Factor 1, mental manipulation items loaded onto Factor 2, and spatial visualization items loaded onto Factor 3

cognitive interviewing techniques, specifically think-aloud interviewing, which involved participants talking aloud as they read and responded to each item and noting points of confusion (e.g., Willis 2004). This technique allowed us to evaluate the items based on how clear and understandable they were, and (for the parents) how relevant they were to real parents. Based on this feedback, several items were modified for clarity and relevance. After the data were collected, we conducted principal axis factoring in SPSS Version 24 with all 24 items, extracting three factors. The rotated pattern matrix, using varimax rotation, is reported in Table 1. Items loaded cleanly on their respective factors, and internal consistencies for all three subscales were good (αs = .84, .94, and .95 for spatial visualization, mental manipulation, and navigation skills, respectively). We therefore created averaged composite scores for each subscale (spatial visualization, mental manipulation, and navigation).

To establish convergent validity of the subscales, we asked parents to report using single-item measures on their child's spatial visualization, mental manipulation, and navigation abilities (i.e., "In general I believe that my child has…" on a scale from 1 = Very low spatial visualization/mental manipulation/navigation ability to 7 = Very high spatial visualization/mental manipulation/navigation ability). Before asking parents to respond to these items, we defined each type of spatial ability clearly, and we provided specific examples of each type of spatial ability (see the online supplement). These items correlated moderately to highly with parents' subscale scores on our measure (rs = .38, .81, and .87 for spatial visualization, mental manipulation, and navigation skills, respectively), demonstrating convergent validity.

To test discriminant validity, we examined whether the correlations between parents' subscale scores on our measure and single-item measures of parents' beliefs about their children's spatial abilities were stronger than the correlations between parents' subscale scores on our measure and a single-item measure of parents' beliefs about their children's math ability. We found that parents' subscale scores on our measure were more strongly correlated with the single-item measures of parents' beliefs about spatial ability (rs = .38, .81, and .87 for spatial visualization, mental manipulation, and navigation skills, respectively) than the single item measuring parents' beliefs about their child's math ability (rs = .04, .55, and .24 for spatial visualization, mental manipulation, and navigation skills, respectively) (Fisher's $Z = 2.64$, $p = .01$ for spatial visualization, $Z = 3.64$, $p < .001$ for mental manipulation, $Z = 7.90$, $p < .001$ for navigation), demonstrating discriminant validity.

Parents' Beliefs about their Children's Math Ability

Parents responded to a single item about their child's math ability adapted from Frome and Eccles (1998): "I believe that my child is…," rated from (*Not at all good at math*) to 7 (*Very good at math*).

Parents' STEM Occupation and Encouragement of their Child

Parents responded to a single item: "To what degree does your current job involve math tasks?," rated from 1 (*Not at all*) to 7 (*A great deal*). Regarding parents' encouragement of their child to pursue a STEM career, parents responded to the single item: "I encourage my child to pursue a career in Science, Technology, Engineering, or Math," rated from 1 (*Not very strongly*) to (*Very strongly*).

Students' Spatial Abilities

Students completed two spatial ability tasks in a counterbalanced order. To assess *spatial visualization skills*, students completed a 60-item hidden figures task (Walter and Dassonville 2011). In the hidden figures task, they were presented with a 4–7 sided polygon and were instructed to search for the exact shape of the polygon within a more complex figure. Students had up to 10 s to respond whether or not the polygon was hiding within the more complex shape. Participants received 1 point for each correct response (max: 60 points).

Mental manipulation ability was assessed using Shepard and Metzler's (1971) mental rotation task. In this task, students were shown pairs of side-by-side images. The images depicted 3D objects made of blocks from the redrawn mental rotation figures image library (Peters and Battista 2008). Students were asked to determine whether the object on the right could be rotated to match the one on the left and responded "yes" or "no" for each pair of objects. Objects that did not match were mirror images. This task included 84 items with objects rotated from 0 degrees (no rotation) to 150 degrees. Two-thirds of the items were matched trials and one-third of the items were mirror image trials. Participants received 1 point for each correct response (max: 84 points).

Students' Preliminary SAT (PSAT) Scores

The PSAT is a standardized test that students in the United States take in high school that includes sections on mathematics and evidence-based reading and writing. Students' PSAT scores were collected from school records. Higher scores indicate better performance on the test. We calculated an overall score by adding their mathematics and evidence-based reading and writing scores. If students took the PSAT multiple times, we used their best score from each subscale. If students took the PSAT after 2016, we used concordance tables to equate the new scores to the old ones, which had a possible range from 60 to 240 (in our data, scores ranged from 118 to 224). (See the online supplement, Table 1s, for a correlation matrix of all variables with the PSAT variables separated by subscale.)

Students' Intentions to Major in STEM

Students were asked to report their intended major in college. Their responses were coded by two independent raters for the degree to which they required mathematics skills based on Goldman and Hewitt's (1976) classification scheme on the following scale: 1 = Fine arts (e.g., Art, Dance, Music), 2 = Humanities (e.g., English, History, Spanish), 3 = Social science (e.g., Anthropology, Economics, Psychology), 4 = Biological science (e.g., Biology, Kinesiology, Zoology), and 5 = Physical science (e.g., Electrical Engineering, Mathematics, Computer Science). Higher scores indicate intentions to major in fields that require stronger mathematics skills. Interrater agreement was high (98.3% exact agreement; $k = .98$).

Students' Intentions to Pursue a STEM Career

Students were asked to report their intended career once they completed all of their education. Two raters coded their responses according to the U.S. Department of Labor's O*Net database (https://www.onetonline.org), which provides descriptions of more than 900 occupations. Each occupation receives a score from 0 to 5 for the level of math skill needed to perform one's job in that occupation, with higher scores capturing intentions to pursue careers that require stronger mathematics skills. Given the large number of career choices listed in O*Net, all disagreements were discussed by the two raters and a third rater until 100% agreement was reached. Skewness and kurtosis statistics indicated that the distributions of all variables were within the normal range (skewness statistics ranged from −.06 to −.84 and kurtosis statistics ranged from −.22 to −1.02; West et al. 1995).

Procedure

Participants were recruited as part of a larger study examining high school students' core spatial abilities, high-level STEM spatial thinking, and neural activity during spatial cognition. Students were recruited from either a Geospatial Science course ($n = 42$, 35.9%) or alternative elective courses ($n = 74$, 63.2%; for one student, course data was missing). Because we were not interested in examining the effects of the course in the present study, we included course as a covariate in all of our analyses. The addition of this covariate did not change the pattern of results; therefore, it was dropped from the analyses reported here. Students took the PSAT in the fall of their first, sophomore, or junior year of high school. In the spring of or the summer following their junior year of high school, students completed the spatial ability tasks. During the late spring of or the summer after their senior year of high school (approximately 1 year later), parents and students completed questionnaires. In the parent questionnaire, parents reported on their beliefs about their child's math and spatial abilities as well as their encouragement of their child to pursue a STEM career. In the student questionnaire, students reported their intended major and career.

Results

Correlations between Variables

See Table 2 for bivariate correlations, means, standard deviations, and ranges for all variables. Positive correlations were found among parents' beliefs about their child's spatial visualization, mental manipulation, and navigation abilities. Of all parent spatial belief variables, parents' beliefs about their child's mental manipulation abilities were correlated with the largest number of additional parent and student variables. These beliefs were positively related to parents' beliefs about their child's math abilities, parents' encouragement of their child to pursue a STEM career, students' actual performance on the mental rotation task, students' intended STEM major, and students' intended STEM career. Parents' beliefs about their child's navigation abilities were positively correlated to parents' beliefs about their child's math abilities and students' intended STEM major. Parents' beliefs about their child's spatial visualization abilities were not correlated with any other additional parent or student variables.

Research Question 1

Research Question 1 asked: Do parents' beliefs about their high school-aged child's math and spatial abilities differ based on students' gender? Do these differences hold when controlling for students' academic and spatial ability? To investigate, we regressed parents' beliefs about their child's math, spatial visualization, mental manipulation, and navigation ability on a dummy-coded gender variable (coded 0 = female, 1 = male). We found no statistically significant differences in beliefs about child math ability ($B = .35$, $SE = .23$, $ß = .14$, $p = .13$) or child spatial visualization ability ($B = -.27$, $SE = .20$, $ß = -.13$, $p = .18$) between parents of young men and parents of young women. However, we did find a statistically significant difference in beliefs about child mental manipulation ability between parents of young men and women, such that parents of young men thought their child had higher mental manipulation ability than did parents of young women ($B = .84$, $SE = .22$, $ß = .35$, $p < .001$). We also found statistically significant differences in beliefs about child navigation ability between parents of young men and women, such that parents of young men thought their child had higher navigation ability than did parents of young women ($B = .60$, $SE = .25$, $ß = .23$, $p = .02$).

In order to determine whether the gender differences in parents' beliefs about their child's mental manipulation and navigation abilities held when controlling for students' actual academic and spatial abilities, we regressed parents' beliefs about their child's mental manipulation and navigation abilities on students' PSAT scores, performance on the mental rotation task (we used this for both analyses because we did not have a measure of students' navigation ability), and a dummy-coded gender variable (coded 0 = female, 1 = male). The statistically significant gender differences in beliefs about mental manipulation ability ($B = .73$, $SE = .23$, $ß = .30$, $p = .002$) and navigation ability ($B = .59$, $SE = .28$, $ß = .23$, $p = .04$) remained, even when controlling for students' performance on the PSAT and the mental rotation task.

Research Question 2

Research Question 2 queried: Are parents' beliefs about their child's spatial abilities associated with parents' encouragement of their child to pursue a STEM career, even when accounting for other likely influences? To investigate, we regressed parents' encouragement of their child to pursue a STEM career on parents' beliefs about their child's math ability, students' PSAT scores, students' performance on a spatial task, student gender, parent gender, and parent STEM occupation (as controls) and parents' beliefs about their child's spatial abilities. We ran four models, three models that only included parents' beliefs about one type of spatial ability (spatial visualization, mental manipulation, or navigation) and one model that included parents' beliefs about all three spatial abilities. We controlled for parents' beliefs about their children's math abilities to examine whether their beliefs about their children's spatial abilities were uniquely associated with

Table 2 Descriptive statistics and correlations for all study variables

Variables	*M* (*SD*)	Range	Correlations											
			1	2	3	4	5	6	7	8	9	10	11	12
1. Parent child-belief – Math	5.63 (1.25)	1–7	–											
2. Parent child-belief – SV	4.74 (1.04)	1–7	.04	–										
3. Parent child-belief – MM	4.73 (1.20)	1–7	.55**	.28**	–									
4. Parent child-belief – N	4.82 (1.31)	1–7	.24*	.35**	.52**	–								
5. Parent STEM encouragement	5.02 (1.83)	1–7	.47**	.09	.43**	.12	–							
6. Parent STEM occupation	4.81 (1.70)	1–7	.13	.13	.13	.08	.08	–						
7. Parent gender	N/A	0–1	.02	−.03	.05	.09	.07	.05	–					
8. Student gender	N/A	0–1	.14	−.13	.35*	.23*	.15	.01	.02	–				
9. Student ability – SV	20.05 (3.65)	12–28	.07	.01	.15	−.07	.15	.08	.13	.03	–			
10. Student ability – MM	64.09 (10.01)	34–80	.28**	.12	.44**	.15	.28**	.10	.07	.35*	.35**			
11. Student PSAT score	166.92 (23.18)	118–224	.36**	.02	.27**	.004	.11	−.04	.13	−.00	.09	.16	–	
12. Student STEM major	3.77 (1.17)	1–5	.31**	−.03	.34**	.25*	.52**	.18	.22*	.01	.04	.05	.01	
13. Student STEM career	2.95 (1.03)	0–5	.15	−.05	.28*	.15	.44**	.09	−.10	.23*	.11	.07	−.03	.53**

STEM Science, technology, engineering, and mathematics, *SV* Spatial visualization, *MM* Mental manipulation, *N* Navigation. Gender is coded 0 = female, 1 = male

*$p < .05$. **$p < .01$

their behavior. We controlled for students' PSAT scores as a measure of general academic ability and their spatial task performance (i.e., the hidden figures task for spatial visualization and the mental rotation task for mental manipulation and navigation) as a measure of their spatial ability. Finally, we controlled for parent gender to account for any differences between mothers and fathers, and parent STEM occupation to account for the fact that parents who have STEM careers themselves may be more likely to encourage their child to pursue a STEM career (Hall, Dickerson, Batts, Kauffmann, & Bosse 2011).

We found that parents' beliefs about their child's spatial visualization and navigation abilities were not statistically significantly associated with their encouragement of their child to pursue a STEM career when accounting for other likely influences. However, parents' beliefs about their child's mental manipulation ability were significantly associated with their encouragement of their child to pursue a STEM career, even when including all control variables. Parents who believed their child had higher mental manipulation ability were more likely to encourage their child to pursue a STEM career. These results held even in the model in which parents' beliefs about all three spatial abilities were included (see Table 3).

In order to test whether student gender moderated these results, we ran all three of the individual models including an interaction term between parent beliefs and student gender (see Table 2s in the online supplement). We found no statistically significant moderation by student gender for any of the spatial abilities.

Research Question 3

Research Question 3 asked: Does parents' encouragement of their child to pursue a STEM career mediate the relation between parents' beliefs about their child's spatial abilities and students' intentions to major in STEM and pursue a STEM career? To explore, we ran two mediation models using the PROCESS macro for SPSS (Hayes 2012), with 5,000 bootstrap samples for bias corrected bootstrap 95% confidence intervals. Because we found that parents' beliefs about their child's mental manipulation ability were the only beliefs that significantly predicted parents' encouragement of their child to pursue a STEM career, we only ran two full mediation analyses, each with parents' beliefs about their child's mental manipulation ability as the predictor (X), parents' encouragement of their child to pursue a STEM career as the mediator (M), and one of the intended career variables (students' intentions to major in STEM or students' intentions to pursue a STEM career) as the outcome (Y). Parents' beliefs about their child's math ability, students' PSAT scores, student performance on a spatial task, student gender, parent gender, and parent STEM occupation were entered as covariates in each model.

In the first analysis, parents' beliefs about their child's mental manipulation ability were significantly related to students' intentions to major in STEM via parents' encouragement of their child to pursue a STEM career. The overall indirect effect

Table 3 Regression analyses of parents' beliefs about their Child's spatial abilities predicting parents' encouragement of their child to pursue a STEM career

	Model 1: Spatial visualization			Model 2: Mental manipulation			Model 3: Navigation			Model 4: All parent child-beliefs		
	B	*SE*	β	*B*	*SE*	β	*B*	*SE*	β	*B*	*SE*	β
Constant	4.85	.27		4.93	.28		4.88	.29		5.02	.30	
Student gender	.22	.35	.06	−.32	.40	−.09	.04	.39	.01	−.35	.43	−.09
Parent gender	.09	.39	.02	.34	.39	.08	.21	.40	.05	.15	.41	.04
Parent STEM occupation	−.03	.18	−.02	−.10	.19	−.05	−.09	.20	−.04	−.15	.20	−.07
Student PSAT score	.002	.19	.001	−.17	.19	−.09	−.09	.20	−.05	−.11	.21	−.06
Student ability – SV	.30	.18	.16							.21	.19	.12
Student ability – MM				.06	.20	.03	.18	.20	.10	−.01	.22	−.00
Parent child-belief – Math	.91	.20	.48***	.72	.22	.38**	.96	.21	.50***	.69	.22	.36**
Parent child-belief – SV	−.004	.18	−.002							−.28	.24	−.14
Parent child-belief – MM				.59	.23	.31*				.66	.28	.35*
Parent child-belief – N							.08	.20	.04	.05	.24	.03
R^2	.29			.32			.28			.35		
F-ratio (*p* value)	4.88 ($p < .001$)			5.31 ($p < .001$)			4.54 ($p < .001$)			3.83 ($p < .001$)		

STEM Science, technology, engineering, and mathematics, *SV* Spatial visualization, *MM* Mental manipulation, *N* Navigation. Gender is coded 0 = female, 1 = male. Parent STEM occupation, student PSAT score, student ability on the spatial visualization and mental manipulation tasks, and parent child-beliefs about math, spatial visualization, mental manipulation, and navigation were standardized

$*p < .05$, $**p < .01$, $***p < .001$

was statistically significant ($B = .20$, $SE = .10$, 95% CI [.01, .41; see Fig. 1). In the second analysis, parents' beliefs about their child's mental manipulation ability were significantly related to students' intentions to pursue a STEM career via parents' encouragement of their child to pursue a STEM career. The overall indirect effect was significant ($B = .15$, $SE = .08$, 95% CI [.003, .32; see Fig. 2).

Discussion

The central purpose of the present study was to examine parents' beliefs about their child's spatial abilities—abilities that are highly relevant to students' STEM outcomes (Wai et al. 2009)—using Eccles' parent socialization model (Eccles et al. 1993a, b) as a framework. Specifically, the parent socialization model posits that parents' beliefs influence parents' behaviors that then influence students' outcomes; we tested these theoretically driven associations in the present study. We found that parents' beliefs were gendered, such that parents of young men thought their child had higher spatial abilities than did parents of young women. In line with the parent socialization model (Eccles et al. 1993a, b), we also found that parents' beliefs about their child's spatial abilities predicted parents' encouragement of their child to pursue a STEM career, which in turn predicted children's own intentions to pursue a STEM major or career. These results held even when accounting for other likely influences, such as parents' beliefs about their child's math ability.

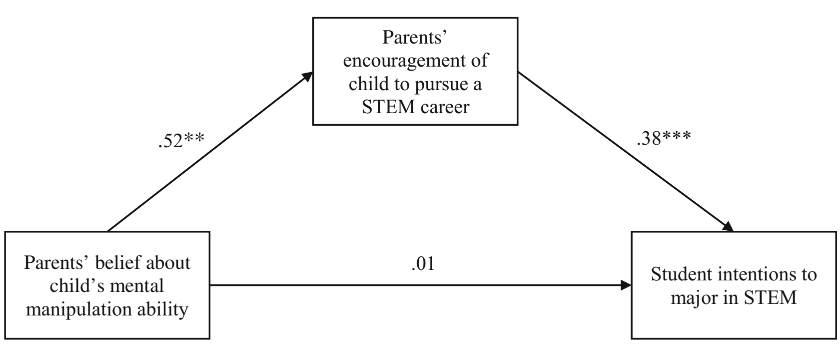

Fig. 1 Mediation model of parents' beliefs about their child's mental manipulation ability predicting students' intentions to major in STEM via parents' encouragement of their child to pursue a STEM career. STEM = science, technology, engineering, and mathematics. Parents' beliefs about their child's math ability, students' PSAT scores, students' performance on the mental rotation task, student gender, parent gender, and parent STEM occupation were entered as covariates. $**p < .01$. $***p < .001$

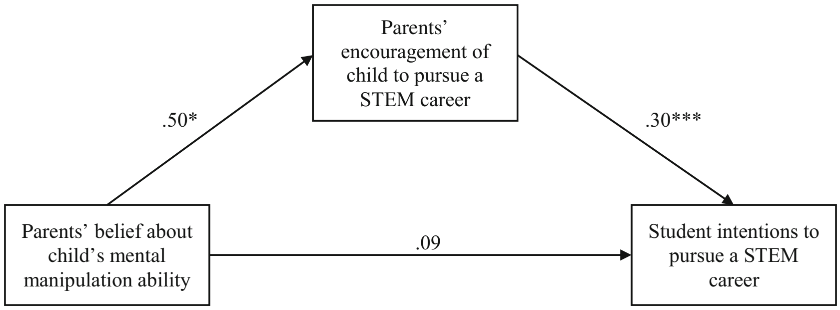

Fig. 2 Mediation model of parents' beliefs about their child's mental manipulation ability predicting students' intentions to pursue a STEM career via parents' encouragement of their child to pursue a STEM career. STEM = science, technology, engineering, and mathematics. Parents' beliefs about their child's math ability, students' PSAT scores, students' performance on the mental rotation task, student gender, parent gender, and parent STEM occupation were entered as covariates. $*p < .05$. $***p < .001$

A strength of the present study is that we examined parents' beliefs about three different types of spatial abilities: spatial visualization ability (i.e., the ability to visualize details in one's mind), mental manipulation ability (i.e., the ability to mentally "transform" an object), and navigation ability (i.e., the ability to successfully move through one's environment). To do so, we used a modified version of the Spatial Anxiety scale (Lyons et al. 2018) that demonstrated good reliability and validity. Thus, we extended previous research (e.g., Furnham et al. 2002) that only looked at parents' beliefs about "spatial intelligence" more generally and identified three different types of spatial ability that have been shown to be distinct yet critical to students' success in STEM fields (Lyons et al. 2018; Uttal and Cohen 2012).

Although we found no gender differences in parents' beliefs about their child's math or spatial visualization abilities, we found that parents of young men believed their child had better mental manipulation and navigation abilities than did parents of young women. These differences held even when controlling for students' PSAT scores and their actual performance on a mental rotation task. Thus, parents appear to hold gendered beliefs about their child's spatial abilities—although our findings suggest that it depends on the *type* of spatial ability under consideration. It is unsurprising that we found gender differences in parents' beliefs about their child's mental manipulation ability, given previous studies that have demonstrated both gender differences and gender stereotypes about mental manipulation/rotation abilities (Halpern 2013; Maeda and Yoon 2013; Reilly and Neumann 2013). However, our finding that parents' beliefs differ even when controlling for students' actual ability suggests that parents' beliefs may be based more on stereotypes than on their child's actual ability, in line with previous work on parents' beliefs about math ability (e.g., Frome and Eccles 1998). Our study is also the first to our knowledge to find that parents hold gendered beliefs about their child's navigation ability (i.e., perceiving young men as having higher navigation abilities than young women), although we were unable to control for students' actual navigation abilities in our analysis.

We did not find evidence for differences in parents' beliefs about their child's math ability based on students' gender, which was somewhat unexpected given previous work that found these differences (Furnham et al. 2002; Parsons et al. 1982; Tiedemann 2000; Yee and Eccles 1988). It could be that highly educated parents (such as those who participated in our study) are more aware of potentially harmful stereotypes about young women's math ability and thus are less likely to be influenced by these stereotypes when evaluating their children's abilities. It is also possible that these gendered beliefs about math ability are decreasing over time because several recent studies—including ours—have not found mean differences in parents' beliefs about math ability based on children's gender (see also, Gladstone et al. 2018; Pesu et al. 2016). However, perhaps gendered beliefs about spatial abilities are stronger and more persistent over time. Given that ours is one of the first studies to examine parents' beliefs about their children's spatial abilities, much more research is needed to investigate this possibility.

Importantly, we found that parents' spatial beliefs matter for students' STEM choices, particularly parents' beliefs about their child's mental manipulation ability. Parents who believed their child had higher mental manipulation ability were more likely to encourage their child to pursue a STEM career (even when accounting for other likely influences). Furthermore, these students were more likely to report intending to pursue a STEM major in college (a more proximal outcome) and a STEM long-term career (a more distal outcome). Interestingly, parents' mental manipulation beliefs were associated with their encouragement of their child to pursue a STEM career above and beyond parents' beliefs about their child's math ability (which was a very strong predictor). This finding suggests that parents' beliefs about their child's math and mental manipulation abilities—although positively correlated ($r = .55$)—are distinct and that parents' beliefs about their child's spatial ability are uniquely associated with their STEM-relevant behavior. This encouragement could take many forms: in parents' words, in their provision of opportunities or activities for their child, or in co-activity (e.g., Simpkins et al. 2012). Future studies should investigate the more specific behaviors that are uniquely predicted by parents' beliefs about their child's spatial abilities.

We found that parents' beliefs about their child's spatial visualization and navigation abilities were not associated with their encouragement of their child to pursue a STEM career. Perhaps parents do not see spatial visualization or navigation abilities as being essential or important to STEM careers, and they therefore view their children's spatial visualization and navigation abilities as irrelevant to their potential success in STEM. This speculation is in contrast to studies that have found students' actual navigation and spatial visualization abilities predict their STEM interest and achievement (Ventura et al. 2013; Wai et al. 2009). However, mental manipulation, which has been tightly linked to STEM achievement (Yoon and Mann 2017; Wai et al. 2009) and has been essential for critical scientific discoveries (e.g., discovery of DNA's structure), emerged as the facet of spatial ability that was both highly gendered and most strongly associated with parent behaviors.

Theoretical implications of our work include providing support for the parent socialization model within expectancy-value theory (Eccles et al. 1993a, b; Simpkins et al. 2012) and extending the model into a new domain: spatial ability. This is particularly important given that parents' beliefs about spatial abilities are highly gendered and—as our findings demonstrate—differentiated from their beliefs about math ability. Parents' beliefs about their children's spatial abilities may therefore be a novel factor that shapes how they socialize young women and men, particularly in STEM contexts. Thus, parents' beliefs about their child's spatial abilities—and the socialization processes that result (e.g., being less encouraging of a daughter than a son to pursue a STEM career)—could potentially help explain the underrepresentation of women in STEM fields (Ceci et al. 2009).

Limitations and Future Directions

Our study has several limitations that should be addressed in future research. First, the cross-sectional design of our study—that is, the fact that parents' and students' beliefs and behaviors were measured at the same time—limits our ability to make causal or directional conclusions about the relation among parents' beliefs, parents' behaviors, and students' outcomes. Although the mediation model that we tested was theoretically driven (i.e., in line with Eccles' parent socialization model), we were unable to fully test the directional and causal links because of the nature of our data. Thus, our analysis should be viewed as exploratory. Despite this limitation, our study is the first known to examine these associations with respect to parents' beliefs about their children's spatial abilities, which is an important contribution to the literature on Eccles' (Eccles et al. 1993a, b) parent socialization model and expectancy-value theory. Future researchers should examine, using longitudinal or experimental designs, the development of both parents' and students' beliefs about spatial ability to better understand the causal links and mechanisms through which parents' beliefs about their child's mental manipulation ability influence students' STEM outcomes, as well as the reciprocal associations between parents' and students' beliefs and behaviors.

Our sample was drawn from a population of parents and students living in affluent urban and suburban U.S. communities who had ample access to technology and opportunities to participate in spatial activities at school (e.g., a Geospatial Science course). Further, all students in our sample planned to attend a 4-year college or university after they completed high school. In the future, researchers should investigate whether these findings generalize to more socioeconomically and educationally diverse populations of students and parents. Additionally, our sample of parents was too small to look at gender differences among parents or interactions between parent gender and child gender. Recent work suggests that mothers' and fathers' beliefs about their child's math ability may differ in important ways and may have different patterns of relations with young men and women's motivation and achievement in STEM (Gladstone et al. 2018), so future work should examine whether this is also the case for parents' beliefs about their children's spatial abilities.

Our measure of parent behavior—encouragement of their child to pursue a STEM career—was measured with a single item and was reported only by parents. Although some work suggests that single-item measures can suffer from poor test-retest reliability (Gliem and Gliem 2003), other research suggests that single-item measures can be appropriate when measuring a very targeted construct (Gogol et al. 2014; Poon et al. 2002). Indeed, previous research that has looked at parental encouragement has also used single-item measures (Simpkins et al. 2006). However, researchers could utilize more robust scales of parent behaviors—and could include measures of how these behaviors are perceived by children—in future work.

In our analyses, we measured STEM majors and careers as continuous variables, such that majors and careers that required more math skills were classified as being more STEM-related. Although math knowledge and skills are fundamental to all STEM careers (Breiner et al. 2012; Moakler Jr and Kim 2014; National Science Board 2015; Watt et al. 2017), there are certainly careers that require strong math skills that would not be technically classified as STEM (e.g., an accountant). Thus, the extent to which majors or careers require math skills is not a perfect proxy for STEM. In the future, researchers could use alternate methods of categorizing STEM majors or careers—perhaps by using a dichotomous

STEM/non-STEM variable—to see if these results still hold. Given that STEM fields are very diverse, future research could also classify STEM fields along different dimensions (e.g., how much they require spatial skills; how underrepresented women or racial/ethnic minorities are in that field) to see if parents' beliefs about their children's spatial abilities more strongly predict whether their children pursue certain types of STEM fields.

Finally, future researchers could unpack additional mechanisms (aside from parent encouragement of their child to pursue a STEM career) by which parents' spatial beliefs influence students' STEM outcomes. For example, parents' conversations with their children about spatial abilities, provisions of spatial opportunities or activities, and the extent to which parents participate in spatial activities with their children could shape students' interest in pursuing a STEM career (Simpkins et al. 2012). Further, parents' beliefs and behaviors likely influence the development of students' *own* beliefs about their spatial abilities (Gunderson et al. 2012). It would be interesting to explore further how students' beliefs about spatial abilities develop from a young age and how parents shape these beliefs.

Practice Implications

From a practical perspective, our findings suggest that parents' beliefs about spatial abilities might be a potential target for interventions—administered by researchers, teachers, or counselors—designed to help support young women's STEM learning, motivation, and career outcomes. It is possible that parents may not be aware of the gender stereotypes they hold about spatial ability—even if they are aware about gender stereotypes about math—or how these stereotypes about spatial ability might influence their beliefs about their own children (specifically their daughters). Thus, interventions could help make parents aware of, and challenge, these potentially harmful stereotypes. Once more research has determined how, exactly, these beliefs about spatial ability are communicated, future interventions could also target specific things that parents do and say to their children that might communicate their beliefs. These interventions could aim to decrease any parent behaviors that might unintentionally communicate low expectations—particularly towards young women—and increase behaviors that would communicate high expectations and provide children more opportunities to develop their spatial skills. Ultimately, these interventions could help to increase young women's motivation and performance in STEM.

Conclusion

In order to increase participation in STEM fields, it is important for researchers to identify what factors predict high school students' intentions to pursue STEM majors and careers. The present study highlights the importance of parents, and it sheds light on one particular factor—parents' beliefs about their child's spatial abilities—that few researchers have investigated. Importantly, our work suggests that parents' beliefs about their children's spatial abilities may be, at least partly, based on gender stereotypes and that these beliefs are associated with parents' own behavior as well as their children's STEM career intentions. Thus, parents' beliefs about their children's spatial abilities—and the socialization processes that result—could ultimately disadvantage women along the STEM pipeline.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval and Informed Consent Data collection was approved by the Georgetown University Institutional Review Board (Study 2016–0152), and informed consent was received by all participants.

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