Undergraduate Gender Differences in Knowledge of the GRE and Perception of the GRE as a Barrier to Applying to Graduate Mathematics Programs

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Graduate Record Examination (GRE) scores are commonly required in applications to graduate school in mathematics. We examine undergraduate mathematics majors' knowledge of the GRE and their perceptions of the GRE as a barrier to applying to these programs as part of a larger project studying student knowledge of the graduate school application process and how it contributes to lack of diversity in graduate mathematics programs. We found that there was an association by gender, and that women were less likely to report that they had heard of the GRE General and Subject Tests. Similarly, women were more likely to report that the GRE tests were a potential barrier to their decision to apply to graduate mathematics programs.

Keywords: Graduate Record Examination, Graduate School Applications, Gender, Social Cognitive Career Theory

The field of mathematics lacks diversity; this becomes more pronounced at higher levels of education. While 50.8% of the U.S. population identify as women and 31.9% as Hispanic/Latinx or African American (U.S. Census, 2020), in recent years only 39% of mathematics bachelor's degrees were earned by women (Golbeck et al., 2019) and 15.9% of mathematics and statistics (mathematics-only data unavailable) bachelor's degrees were earned by minoritized[1] students (National Center for Science and Engineering Statistics, 2019). At the highest levels of formal education, only 24.1% of new mathematics doctoral recipients were women and 7.4% were minoritized (Golbeck et al., 2020).

Many graduate programs in the U.S. require students to take the Graduate Record Examination (GRE) General Test, and some programs also require the discipline specific test as well (e.g. mathematics, physics). Graduate programs often use the GRE to gauge applicants' preparedness for graduate school. Despite recommendations against this practice from the ETS (Miller et al., 2019; Posselt, 2016), some programs advertised cut off scores for the Subject and General Test in order to apply (Miller et al., 2019; Petersen et al., 2018). Other programs weigh GRE performance heavily to speed up the review process (Petersen et al., 2018; Posselt, 2016). The frequent use of cut off scores and heavy weighting of the GRE led to investigation into whether these practices disadvantage certain groups. Studies found that minoritized students and women score lower on the GRE than their counterparts (Bleske-Rechek & Browne, 2014; Cochran et al., 2018; Miller et al., 2019; Petersen et al., 2018). In fact, women and minoritized students were less likely than their peers to score above a program's stated Subject Test threshold, which reduces their chances of being accepted to a given program (Miller et al., 2019;

[1] Minoritized is an alternative way of referring to people who are often labeled as "Underrepresented Minorities" in STEM. This alternative phrasing makes it clear that it is power imbalances and systematic oppression that cause these groups to be less represented in STEM (Wingrove-Haugland & McLeod, 2021).

Posselt et al., 2019; Verostek et al., 2021; Young & Caballero, 2021). Several other studies found similar results for the General Test (Petersen et al., 2018; Posselt et al., 2019). Building on these results, researchers have investigated whether the GRE predicts PhD completion, finding that GRE performance does not predict PhD completion or success in a PhD program (Miller et al., 2019; Petersen et al., 2018; Roberts et al., 2021; Wilson et al., 2018). So, while the usefulness of the GRE in predicting success is uncertain it still often serves as a barrier for women and minoritized students pursuing graduate education. In this paper we examine data related to what undergraduate mathematics majors know about the GRE as they prepare to apply to graduate school.

This study is part of the Undergraduate Knowledge of the Mathematics Graduate School Application Process (Knowledge-GAP) project which was created to explore undergraduate mathematics majors' knowledge about the graduate school application process and differences in perceived barriers to applying to graduate school across different demographic groups. This paper focuses on the results related to the GRE. Specifically, we examined differences in knowledge and perceptions of the GRE between graduate school applicants.

1. *What do undergraduate mathematics majors know about the GRE?*
2. *Do knowledge and perception of the GRE differ by gender identity of the students?*

Theoretical Background

Social Cognitive Career Theory (SCCT) incorporates Tinto's non-cognitive and contextual factors known to be important in retaining minoritized students and women and expands them for use in STEM career choice for these groups (Lent et al., 1994, 2000; Tinto, 1975, 1993, 2007). Tinto's sense of academic belonging is particularly important for student groups marginalized in STEM; SCCT refines this aspect and identifies several additional significant barriers affecting degree interest and completion for minoritized students and women, each of which are exacerbated by institutionalized environmental barriers at every level of education (Alexander & Hermann, 2016; Cutright et al., 2015; Estrada et al., 2016). The SCCT model incorporates gender as an individual characteristic and situates it within a person's context specific characteristics. Kanny et al., (2014) discussed SSCT studies focusing on individual characteristics (e.g. race, ethnicity), structural barriers (e.g., institutional and classroom climates), psychological factors (self-efficacy or sense of belonging), and family influences (including gender role socialization and self-concept), and perceptions of STEM careers. Within the SCCT framework, each of these contextual factors impacts career trajectory by acting as either a facilitator or a barrier and they may even be the key factors influencing lower participation of women and minoritized people in STEM careers. For example, racist and sexist systemic barriers may affect both the entrance and persistence of marginalized groups in STEM careers by negatively influencing their STEM self-efficacy and their STEM career outcome expectations.

Within this framework, we view the GRE as representative of a structural barrier for some groups of students wishing to enroll in graduate programs in mathematics. A recent study of mathematics graduate programs at three large research universities reported that only 18%, 15%, and 12% of applicants were women, respectively (Gevertz & Wares, 2020). Given the widespread use of the GRE as an application requirement, gender differences in knowledge of and perception of the GRE as a barrier to applying has the potential to impact the demographics of mathematics graduate education.

Methods

Instrument Development

The research team created a survey based, in part, on a survey used to determine undergraduate physics majors' interest in graduate school and how important they believed different aspects of the application process were (Chari & Potvin, 2019). Nineteen survey items were adapted from that instrument, though a notable difference in our survey was that we provided an opportunity for participants to express their lack of knowledge about different parts of the application process. The final survey had 57 items separated into four categories: (a) knowledge about different aspects of the application process, (b) barriers to applying, (c) interest in graduate school and what students look for in programs they apply to, and (d) demographic questions. Most questions were Likert scale or multiple choice, though four were open-ended and some of the multiple-choice items allowed participants to type in a text response. The full survey is available at this link: https://researchrepository.wvu.edu/faculty_publications/3291/

Data Collection

To ensure broad participation, the research team sent the survey to department chairs and undergraduate program directors at all undergraduate mathematics programs at colleges and universities in the U.S. with at least 1000 students total ($N = 985$). We asked programs to send the survey to all undergraduate mathematics majors. Initial emails were sent Fall 2022 through Spring 2023, via Qualtrics, and follow-up emails were sent to encourage a greater response rate. In addition to direct emails, the research team also posted the survey on social media, listservs, and in newsletters for several professional organizations in mathematics.

Data Analysis

We received 1090 responses from students at 181 colleges and universities, with 519 complete responses. Note that students could miss part of a question and still have their response marked as complete. Thus, the *N*s for different items are not always the same. Statistical tests were run in IBM SPSS.

To address our research questions, we analyzed responses to five survey items. Three were binary response items asking participants about the following aspects of both the GRE General Test and Mathematics Subject Test: if they had previously heard of, or taken, the tests; if they knew about the different sections on the test, testing modality options, testing frequency and locations, costs associated with taking exams and having scores sent to institutions, and availability of fee waiver codes. The final two were the Likert scale items: *To what extent are the following factors a potential barrier to your pursuit of graduate school?* and *How important are the following factors in choosing which schools you apply to?* Both items were adapted for our study from Chari and Potvin (2019). The first item had 17 sub-item topics, rated on a scale of 1 (not at all a barrier) to 5 (very significant barrier). The second item had 15 sub-item topics, rated on a scale of 1 (not at all important) to 5 (very important). For this paper we only analyze responses to the seven sub-item topics related to the GRE.

Results

Participant Demographics

Table 1 shows demographics of participants with complete responses. Participants were able to select more than one option for gender, so the total adds up to more than 100%.

Table 1. Self-identified Gender.

What is your gender?		
Gender	*N*	Percentage
Man	251	48.4%
Woman	226	43.5%
Genderqueer or Non-Binary	41	7.9%
Agender	12	2.3%
Transgender	21	4.0%
A gender not listed	2	0.4%
Prefer not to say	8	1.5%
Total	519	

Knowledge of the GRE

Overall participant knowledge of the GRE was incomplete at best. While a majority of the participants (379/518, or 73.2%) had heard of the test before, only half (270/518, or 52.1%) had heard of the GRE Mathematics Subject Test. More worryingly, when asking participants who had heard of the GRE what specifically they knew about the exam, there were large gaps in specific knowledge about the exam. Of the 346 participants who said they had heard of the GRE General Test before, only about half (50.7%) knew that the test had three sections: Verbal Reasoning, Quantitative Reasoning, and Analytical Writing. Only about half of those participants (168/346, or 48.6%) knew that the test is offered with regular frequency, and that it is possible to take it from home. For questions pertaining to the cost of the exam, only a third of participants (115/346, or 33.2%) knew the cost of the test ($220). Just over a fifth of participants (74/345, or 21.4%) knew that it costs $30 to send GRE scores to a graduate program after taking the test and just over a fifth (79/345, or 22.9%) knew that fee waivers were available for the GRE.

For the GRE Mathematics Subject Test, of the 267 participants who said they had heard of the test before, only about a third (96/267, or 36.0%) knew that the test is only available three times a year. About 40% (107/267) knew that at the time the survey was administered, the test was not available to take from home and you had to travel to a testing center to take it. Finally, only 30.5% (81/266) knew the cost of the test ($150).

It is necessary to mention that these results are for a subset of the larger sample. For example, 36% of participants who had heard of the Mathematics Subject Test knew how often the tests are available, but only 52% of participants overall had heard of the Mathematics Subject Test. Therefore, the percentage of participants overall who knew how often the Mathematics Subject GRE is offered was only 96/518 = 18.5%. In addition, only a small number of participants had taken either of the two GRE tests before taking the survey: 50/518, or 9.7%, for the General Test and 25/518, or 4.8%, for the GRE Mathematics Subject Test.

Based on the established literature on gender and GRE performance we tested if there was a difference in knowledge or perception of the GRE as a barrier by participant gender. One issue we encountered in our data analysis was that our participants were not limited to a gender binary like most previous studies of the GRE. To get results comparable to previous studies participants were separated into two groups based on their answer to the survey item asking for their gender. Participants who said they were women, regardless of whether they selected any additional gender identities were labeled as “Women” for our analysis. This includes women who are also cisgender, agender, transgender, and/or non-binary. Similarly, participants who did not select the

women option were labeled as “non-women”. We use this categorization to have results comparable to studies that had a binary definition of gender, while also being inclusive of our participants’ other identities. We found that there was an association by gender, women were less likely to say they had heard of the GRE General Test before taking the survey $\chi 2(1, N = 518,) = 13.47$, $p = <.001$ ($V = .16$). Similarly, there was an association by gender, and women were less likely to say they had heard of the GRE Mathematics Subject Test before taking the survey $\chi 2(1, N = 518) = 14.95$, $p = < .001$ ($V = .17$). Both results had a small effect size. There were no associations by gender for the other survey items about knowledge of the GRE (All p’s > .05).

Perception of the GRE

We report here on the GRE-related sub-item topics for the two Likert scale items, five for the first item and two for the second item. A one-way analysis of variance (ANOVA) was not employed because for 3 of the 7 sub-item topics the Homogeneity of Variance assumption was violated. Thus, for ease of comparison and consistency, Mann-Whitney U tests were performed using the women/non-women variables for all sub-item topics. Table 2 contains Mann-Whitney U test results for the women/non-women groups for the 519 participants who responded to the selected sub-item topics from the first item. The output of a Mann-Whitney U test is a Z value on a normal distribution. The Z values in Table 2 indicate that the women group has greater means than the non-women group. These results show there is a statistically significant difference (all p’s < .05) between the women/non-women groups in the responses for all five sub-item topics. In all cases, women were more likely to view each sub-item topic as a potential barrier to their pursuit of graduate school than their peers. All these results had a small effect size (all r’s between 0.1 and 0.3).

Table 2. Mann-Whitney U test results for selected items for the question “To what extent are the following factors a potential barrier to your pursuit of graduate school?” using the women/non-women variable.

Item	Group	N	Mean	Mean Rank	U	Z	p	r
The need to do well on the GRE General Test	Women	226	3.08	295.28	24684	-5.01	<.001	0.22
	Non-Women	291	2.57	230.82				
The need to do well on the GRE Mathematics Subject Test	Women	226	3.37	301.06	23376.5	-5.80	<.001	0.26
	Non-Women	291	2.75	226.33				
Paying for the General GRE Test ($220)	Women	225	3.10	289.42	25556	-4.32	<.001	0.19
	Non-Women	290	2.57	233.62				
Paying for the GRE Mathematics Subject Test ($150)	Women	225	3.05	291.35	25571	-4.42	<.001	0.19
	Non-Women	292	2.51	234.07				
Sending GRE scores to programs ($30 per program)	Women	224	2.84	283.58	27086.5	-3.44	<.001	0.15
	Non-Women	292	2.43	239.26				

For the second survey item, "How important are the following factors in choosing which schools you apply to?", it should be noted that not all participants saw this item. Prior to this, survey participants were asked to state their interest in graduate school in mathematics. Only participants who responded with anything other than "Not interested in graduate school in mathematics" saw this item. Table 3 contains Mann-Whitney U test results for the women/non-women groups for the 438 participants who responded to the selected sub-item topics from the second survey item. The *Z* values in Table 3 indicate that the women group have greater means than the non-women group. Results show a statistically significant difference (all p's < .05) between the women/non-women groups in the responses for all five sub-item topics. The women were more likely to view each sub-item topic as an important factor in choosing which school to apply to than their peers. All results had a small effect size (all r's between 0.1 and 0.3). These Mann-Whitney U test results show that women are more concerned about all aspects of the GRE compared to their peers.

Table 3. This table provides Mann-Whitney U test results for selected items for the question "How important are the following factors in choosing which schools you apply to?" using the women/non-women variable.

Item	Group	*N*	Mean	Mean Rank	*U*	*Z*	*p*	*r*
No GRE General Test requirement or no minimum score requirement	Women	184	2.83	240.37	19344.5	-3.10	.002	0.15
	Non-women	253	2.46	203.46				
No GRE Mathematics Subject Test requirement or no minimum score requirement	Women	184	2.99	248.55	18022.5	-4.19	<.001	0.20
	Non-Women	254	2.47	198.45				

Discussion

Overall, we found that while students may have heard of the GRE, they rarely had detailed knowledge of the exam, including where and when it is offered, and its associated costs. Those last two points are especially problematic; if students miss the deadline or do not have the finances to afford the exam, they cannot apply to any program that requires GRE scores. The financial barrier is particularly a problem, since minoritized students often come from lower income families than their peers, and thus are more likely to have the cost of the GRE serve as a barrier to applying to graduate school (McEldowney et al., 2024). Since this survey was conducted, the Educational Testing Service recently changed many aspects of how they offer both the GRE General and Subject Tests, including offering them remotely (Educational Testing Service, 2023a, 2023b). This did not impact our results since these changes occurred after data collection was completed.

We contribute to the literature on gender differences in GRE test scores by finding gender differences in knowledge and perception of the GRE. Women were less likely to have heard of either GRE test, but for those who had heard of the exam their knowledge of the exams was not statistically different from other participants. More research is needed to determine the cause of this observed difference. As for perception of the GRE, women were more likely to state that the GRE, both the General Test and Mathematics Subject Test, were barriers to applying to graduate school. Women were also more likely to favor applying to programs with less rigorous GRE requirements. Given the established literature showing that womens' average scores are lower

than their peers on the GRE, which disadvantages them in the application process, (Bleske-Rechek & Browne, 2014; Miller et al., 2019; Petersen et al., 2018) it is not surprising that women would view these exams negatively. Our results demonstrate that the GRE acts as an institutionalized environmental barrier, as proposed by SCCT, that affects degree interest and interest in applying to programs is perceived differently depending on the gender of the participant.

A recurring part of the conversation surrounding the GRE is whether it should be part of the graduate admissions process. During the height of the pandemic many programs dropped the GRE due to unavailability. Even now many programs have decided to continue not requiring the GRE (Google, n.d.). Many disciplines have dropped the subject GRE requirement altogether to the point where the ETS now only offers three subject tests: Mathematics, Physics and Psychology. There are very few studies of the Mathematics Subject GRE, though there is research on the reliability and impact of the Physics Subject Test (Miller et al., 2019, Young & Caballero, 2021). We challenge the research community to study the Mathematics Subject GRE to this level of rigor.

An important consideration we had for this paper was how to utilize the provided demographic information of our participants. Most existing research on the GRE assumes a gender binary while our results give a more honest and interesting reflection of gender among American college students. To tie our work back to the established literature we decided to use the women/non-women categories. While this categorization is imperfect, it was the most ethical solution we found to run statistically meaningful tests. That said, we call on future researchers to use gender beyond the binary in their quantitative research. New formulations and solutions will be needed to do this well, but we owe that to our participants.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Number 2126018. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

We also acknowledge Emily T. Winn-Nuñez, the creator of the GRE Database that tracks the GRE requirements of over 200 mathematics graduate programs (Google, n.d.). She was consulted when designing the Knowledge-GAP instrument items on the GRE and has been a consistent source of information on GRE availability and changes.

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