

Behind the graduate mental health crisis in science

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Survey results identify how scientific research and teaching contribute to the graduate student mental health crisis.

In 2018, researchers declared a “graduate student mental health crisis” after finding that master’s and PhD students were significantly more likely to report anxiety and depression compared to their peers in the general population¹. The crisis garnered particular concern within the scientific community^{2,3} given the notoriously stressful culture of science⁴ and the disproportionate effect that anxiety and depression are known to have on identity groups that the scientific community is trying to recruit and retain, including women^{1,5,6}, individuals from

low socioeconomic backgrounds⁷, members of the LGBTQ+ community^{1,8}, individuals with marginalized racial or ethnic identities⁹ and people with disabilities¹⁰. As a result, scientific organizations amplified the urgent need to make science graduate education more inclusive for students struggling with mental health^{11–14}. However, over the past 5 years, graduate student mental health has continued to deteriorate^{15–17}, partially owing to the paucity of knowledge about how science graduate programs affect students’ mental health¹⁸.

Earlier studies have focused on broad aspects of the graduate experience that affect student mental well-being, including poor mentor–mentee relationships^{1,19–23}, financial stress^{4,8,20,23}, lack of work–life balance^{1,2,14,20,22,24}, failure to replicate results²⁵ and uncertainty about their future career^{2,20,21}. Notably, these aspects were hypothesized by study authors and not articulated by graduate students themselves. Further, no studies exclusively examined how specific aspects of the two most common components of science graduate education, research and teaching, impact

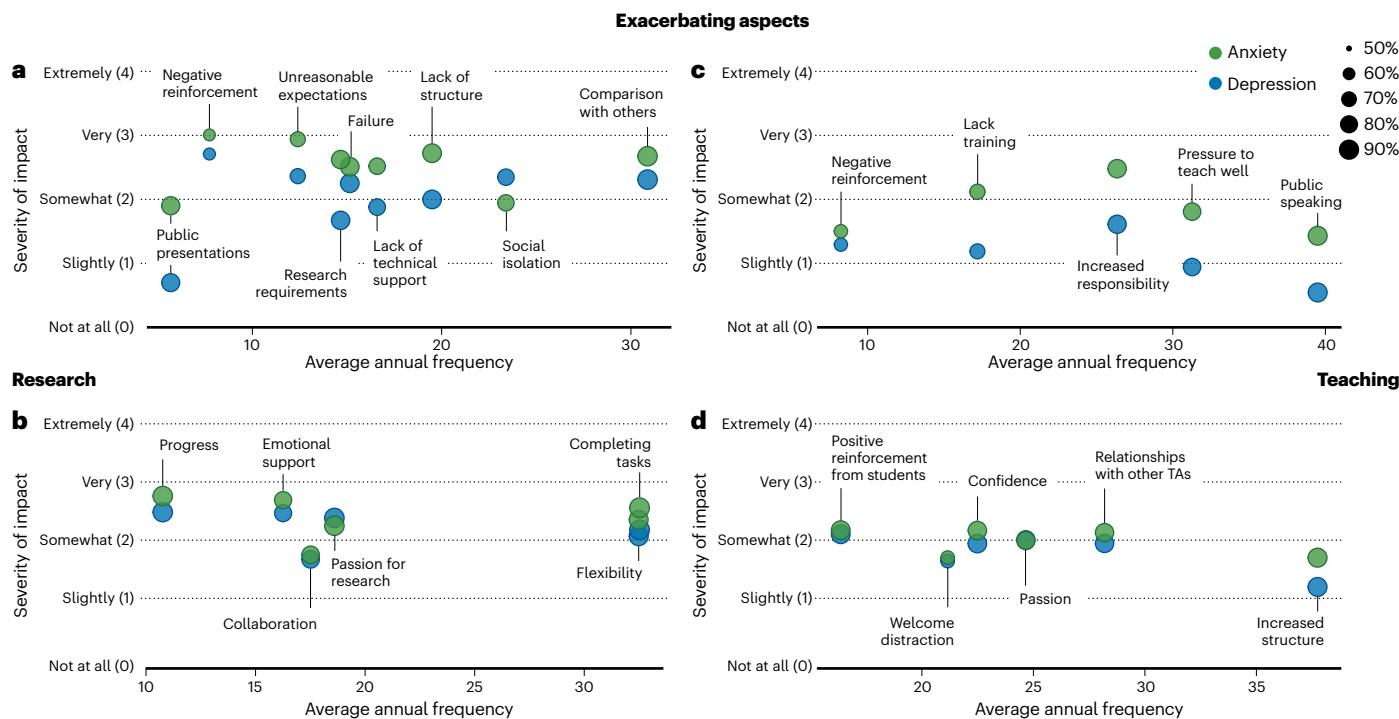


Fig. 1 | The average annual frequency encountered and the corresponding average severity of impact of aspects of research and teaching that exacerbated and alleviated graduate students’ symptoms of anxiety and/or depression. (a–d) Aspects of research that exacerbate (a), aspects of research

that alleviate (b), aspects of teaching that exacerbate (c) and aspects of teaching that alleviate (d) anxiety (green) and depression (blue). The size of the point corresponds to the percent of participants with anxiety or depression who reported experiencing the aspect.

Careers & recruitment

Table 1 | Summary of regression results for the effect of individual characteristics on the impact of aspects of research and teaching that exacerbate or alleviate anxiety and depression

Aspect	Gender	Race/ethnicity			LGBTQ+	Financially stable	Year in program
	Women or nonbinary	Asian	Black	Latinx	Yes	Not always	Less than 3
Aspects of research that exacerbate anxiety and/or depression							
Failure	△▲				△▲	△▲	▼
Lack structure	△				△▲	△▲	▼
Negative reinforcement	△▲				△▲		
Unreasonable expectations	△▲		▽▼		▲		
Comparison with others	△▲				▲	△▲	
Lack technical support	△				△	△▲	▼
Social isolation	△▲				▲	△	
Public presentations	△	▲				▲	
Requirements	△	▲				▲	
Aspects of research that alleviate anxiety and/or depression							
Complete tasks	△		△				
Progress	△						
Collaboration							
Passion			△			△	△▲
Flexibility	△▲			△▲			
Emotional support	△▲						
Aspects of teaching that exacerbate anxiety and/or depression							
Increased responsibility	△	▲				△▲	
Negative reinforcement	△▲	▲				△	
Pressure to teach well	△▲	▲				△▲	△▲
Lack of training	△▲					△▲	△▲
Public speaking	△▲	▲				△▲	
Aspects of teaching that alleviate anxiety and/or depression							
Positive reinforcement							
Increased structure	△▲	△▲	△▲	△			
Passion					△		▼
Welcome distraction		△		△			▽▼
Confidence	△		△				
Relationships with TAs	△	△	△	△	△	△	△

Open triangles indicate anxiety and filled triangles indicate depression. The direction of the triangle point corresponds to whether the group was significantly more likely (upward-facing) or less likely (downward-facing) to report a greater impact of the aspect compared with the reference group. Reference groups: men, white, not LGBTQ+, financially stable and with three or more years in the graduate program. Significance was determined based on false discovery rate (FDR)-adjusted *P* values using Benjamini–Hochberg corrections, with an adjusted *P*-value threshold of 0.05. Full results are presented in Supplementary Tables 5 and 6.

students' mental health. To address these gaps, we conducted in-depth interviews of science PhD students with anxiety (C.J. Pigart et al., unpublished data) and depression²⁶, probing what specific aspects of research and teaching alleviate and exacerbate their respective symptoms. We used the results of the interview studies to develop a mental health survey of science graduate students

so that we could explore the prevalence and effects of mental health struggles at scale. Here, we report on the results of the mental health survey of 2,161 master's and PhD students across 142 US institutions to determine what aspects of research and teaching alleviate and exacerbate graduate students' symptoms of anxiety and depression. In turn, we report the ways in which students' anxiety and

depression impact their research and teaching (see survey questions in Supplementary Information). We also examine the extent to which personal demographics (for example, gender, financial stability) and program characteristics (for example, degree type, field of study) predict graduate student experiences with mental health (see Methods in Supplementary Information).

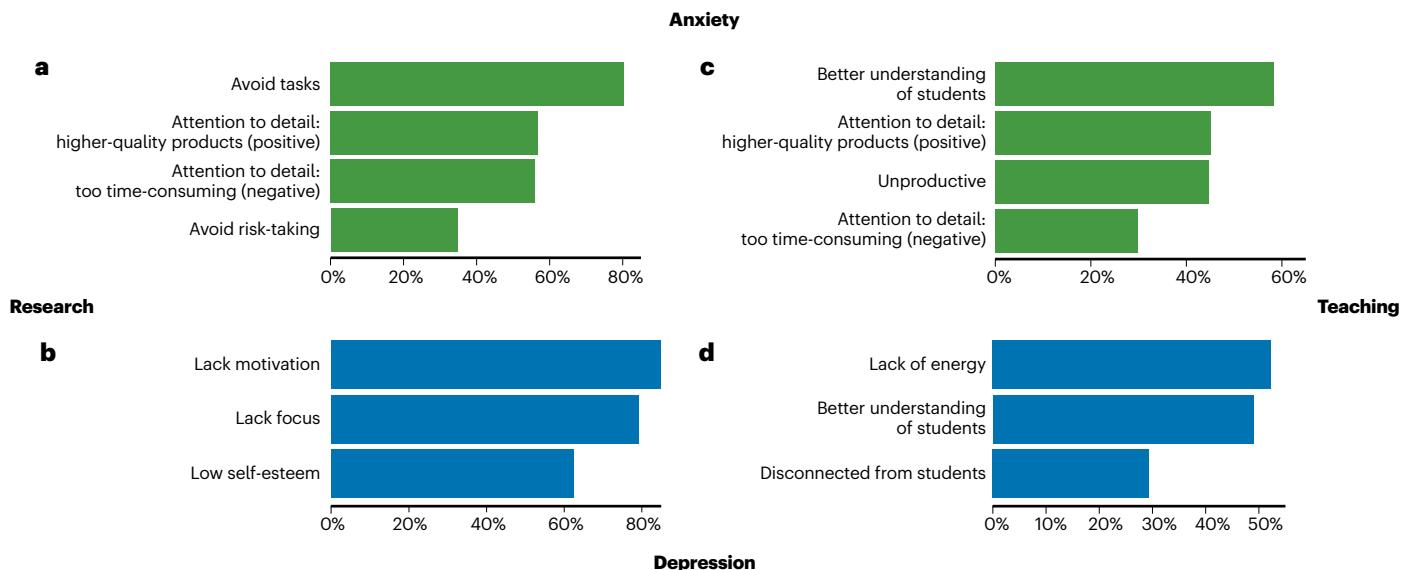


Fig. 2 | The impact of anxiety and depression on graduate research and teaching. (a–d) The percentages of participants who reported specific ways that their research is affected by their anxiety (a) and depression (b) and who reported specific ways that their teaching is affected by their anxiety (c) and depression (d).

Our sample (fully summarized in Supplementary Tables 1 and 2) consisted of graduate students who self-identified as having either anxiety (9%) or depression (13%), or both anxiety and depression (78%), and were enrolled in either a thesis-based master's (22%) or PhD (78%) program in the sciences, including biology (44%), chemistry (22%), physics (16%) and geosciences (12%). Of students who identified as having anxiety, over half (51%) described their anxiety during their graduate program as moderate, 16% as mild and 31% as severe. With regard to depression, the greatest number (49%) reported moderate depression during their graduate program, 24% reported mild depression and 23% reported severe depression. Our sample included graduate students who had been enrolled in their programs from 1 year or less (29%) to 7 years or more (1.6%). Over 80% of participants reported having served as a teaching assistant (TA). Participants included women (61%), men (34%) and nonbinary (4%) students, those who identified as white (68%), Asian (16%), Latinx (8%) and Black (3%) and students who were (49%) and were not (51%) financially stable.

Effects of research and teaching on graduate student mental health

Science graduate students reported how frequently they experienced aspects of research and teaching that exacerbated and alleviated their symptoms of anxiety and/or depression,

as well as how severely each aspect affected their mental health (Fig. 1a–d; Supplementary Table 3). Negative reinforcement, such as receiving overly harsh criticism or being scolded by a research mentor, and being held to unreasonable expectations were two of the most detrimental aspects of research affecting student mental health (Fig. 1a). Conversely, making progress in research and receiving emotional support alleviated students' symptoms of anxiety and depression (Fig. 1b). Feeling burdened by the increased responsibilities that come with teaching, and a lack of teacher training, both exacerbated students' struggles with anxiety in particular (Fig. 1c), whereas positive reinforcement from undergraduates, such as positive comments on teaching evaluations, alleviated symptoms of both anxiety and depression among graduate students in the context of teaching (Fig. 1d). Overall, aspects of research and teaching had greater exacerbating effects on student anxiety than on depression (odds ratio (OR) = 2.08, $P < 0.001$) and, to a lesser extent, greater alleviating effects on anxiety than on depression (OR = 1.24, $P < 0.001$) when we controlled for the severity of anxiety or depression. Additionally, compared with aspects of teaching, aspects of research had both a greater exacerbating effect (OR = 2.93, $P < 0.001$) and a greater alleviating effect (OR = 1.70, $P < 0.001$) on graduate mental health when we controlled for severity of condition (full results in Supplementary Table 4).

Repercussions of research and teaching on student mental health are experienced unequally

Students who are women or nonbinary, LGBTQ+ or not financially stable reported that aspects of research had a greater exacerbating effect on their anxiety and depression than did their respective counterparts (Table 1; Supplementary Tables 5 and 6). Additionally, women or nonbinary graduate students generally reported that aspects of research had disproportionate alleviating effects on their anxiety. With regard to aspects of teaching, women or nonbinary graduate students, those not financially stable and those less than 3 years into their program reported that aspects of teaching exacerbated their symptoms of anxiety and depression more severely than did their respective counterparts. However, some aspects of teaching disproportionately alleviated symptoms of anxiety for women or nonbinary, Asian, Latinx and financially unstable students. For most of the associations between demographic characteristics and the impact of aspects of research and teaching on anxiety and depression, the severity of anxiety or depression partially mediated the relationship (Supplementary Tables 7 and 8 and Supplementary Fig. 1). There were few significant effects of program characteristics (that is, degree type and field of study) on the aspects of research and teaching that exacerbated or alleviated anxiety or depression (Supplementary Table 9). Graduate students

in biology sometimes reported that aspects of research and teaching had a more severe impact on their anxiety and depression compared with physics students, and master's students sometimes reported that aspects of research and teaching had a greater impact on their anxiety and depression compared with PhD students.

Impact of anxiety and depression on graduate research and teaching

Most graduate students with anxiety reported that their anxiety affects their research primarily by causing them to avoid tasks (Fig. 2a), and graduate students with depression reported that it affects their research by causing a lack of motivation and a lack of focus (Fig. 2b). Graduate students who were not financially stable or were in their third year or later were more likely to identify aspects of anxiety or depression that affected their research (Supplementary Table 10), which was often at least partially mediated by the severity of anxiety or depression (Supplementary Table 11). There were no program characteristics associated with the impact of depression and only two associated with the impact of anxiety on graduate research: PhD students were more likely than master's students to indicate that anxiety can result in a lack of risk-taking that negatively impacts their research (adjusted $P = 0.02$), and biology students were more likely than physics students to indicate that their anxiety causes better attention to detail that yields better-quality products (adjusted $P < 0.001$; Supplementary Table 12).

Graduate students reported that their anxiety benefits their teaching because they have a better understanding of students and because their attention to detail yields better-quality results (Fig. 2c), and they reported that their depression affects their teaching by causing a lack of energy (Fig. 2d). Similar to the effect of anxiety and depression on research, graduate students who were not financially stable or in their third year or later in graduate school were more likely to identify aspects of anxiety or depression that affect their teaching. LGBTQ+ students perceived that their anxiety and depression affect their teaching to a greater extent than non-LGBTQ+ graduate students (Supplementary Table 10). For many of the ways in which students' anxiety or depression affected their teaching, this relationship was at least partially mediated by severity of anxiety or depression (Supplementary Table 11). Graduate students in chemistry reported that aspects of anxiety or depression affect

their teaching more than biology students did (Supplementary Table 12).

Severity of anxiety and depression is associated with contemplating departure from graduate school

Graduate students who identified as having depression were more likely to report having changed principal investigators (PIs) than students with less severe depression (moderate depression: $OR = 1.52, P = 0.03$; severe depression: $OR = 2.17, P < 0.001$; anxiety $P > 0.05$; Supplementary Table 13). Of students with depression who changed PIs, 69.3% perceived that it increased the amount of time required to complete their graduate program. Further, students with more severe anxiety or more severe depression were more likely than those with less severe anxiety and depression, respectively, to report having considered leaving their graduate program (moderate anxiety: $OR = 1.60, P < 0.001$; moderate depression: $OR = 1.96, P < 0.001$; Supplementary Table 13). Graduate students with severe anxiety had nearly three times higher odds of considering leaving their program than graduate students with mild anxiety ($OR = 2.97, P < 0.001$), and students with severe depression had over five times higher odds of considering leaving their program compared with those who reported mild depression ($OR = 5.47, P < 0.001$).

Discussion

This research provides needed insight into what specific aspects of research and teaching affect science graduate students' mental health and provides a roadmap for future interventions. Our findings indicate that both anxiety and depression can have a substantially detrimental impact on graduate students' experiences in both research and teaching environments and likely also contribute to increased time to degree and student attrition. Given that students from under-represented and underserved groups are disproportionately likely to experience anxiety and depression, we argue that addressing aspects of graduate school that exacerbate students' mental health symptoms is a novel and necessary approach to creating a more diverse and inclusive scientific community.

Our results illuminate aspects of research and teaching commonly encountered by graduate students that worsen mental health, including experiencing isolation in research and experiencing pressure to teach well. Creating organizations that provide social support alongside professional development^{12,27,28} and facilitating peer mentorship²⁹ may be

particularly effective in promoting social relationships among graduate students. Additionally, providing adequate teacher training, especially in light of the sparse opportunities in graduate school³⁰, would likely be protective of science graduate student mental health^{26,31}. Science graduate students who are not financially stable disproportionately reported that anxiety and depression affect their research and teaching, suggesting that calls to provide greater financial support to students^{32,33} may simultaneously support graduate student financial stability and mental health and wellbeing³⁴. Although mentoring has been well-established as an aspect of graduate school that impacts students' mental health^{1,35}, and effective mentoring has been championed for decades^{36–38}, our study revealed aspects of mentoring that are specifically harmful and helpful to students. Negative reinforcement, such as harsh criticism, was found to be especially deleterious to students' mental health, whereas emotional support was found to help alleviate symptoms. As such, training mentors to provide criticism constructively and to engage with students' emotions during their extended time together appears especially timely^{39,40}.

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Author contributions

C.A.B., N.J.W., L.E.G. and K.M.C. collected the data. C.A.B. analyzed the data. C.A.B. and K.M.C. wrote the manuscript with input from all authors. K.M.C. provided supervision and acquired funding.

Competing interests

The authors declare no competing interests.

Additional information

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