Student Mental Health during Summer 2022 Research Experiences for Undergraduates (REUs): Mentorship, Remote Engagement, and COVID-19

Abstract

Objective: We examined how mentorship, remote participation, and COVID-19 challenges were associated with the mental health of college students participating in summer research programs.

Participants: Participants were students participating in 78 National Science Foundation (NSF) Research Experiences for Undergraduate (REU) Sites during Summer 2022 (*n*=516 students).

Methods: We used multivariable generalized estimating equations that account for clustering by REU Site.

Results: Students with more competent mentors had reduced depression severity. Students who spent ≥25% of their time doing remote research or ≥25% of their time in remote meetings and workshops had greater depression severity. Remote research was associated with anxiety severity. Having a COVID-19 challenge that impacted students' research experience was associated with increases in depression and anxiety severity.

Conclusions: Results suggest potential interventions: implement strategies to boost mentor competency and scaffold a support system into summer research programs to enhance student wellbeing. Additional research on remote engagement is needed.

Key words: anxiety; depression; National Science Foundation (NSF) Research Experiences for Undergraduates (REU) Sites; mentorship, COVID-19, remote research, summer undergraduate research experiences (SUREs)

Introduction

College students are a particularly vulnerable group to mental health stressors. Approximately 75% of lifetime psychological disorders develop during young adulthood[1]. The onset of the COVID-19 pandemic worsened college students' mental health[2, 3], but this trend of increasing mental health problems for college students predates COVID-19[4, 5]. In 2017-2018, 34.4% of US college students struggled with moderate-to-severe anxiety and 41.1% suffered from moderate-to-severe depression[6]. Rates of anxiety and depression remained elevated during the 2021-2022 school year:37% of students reported moderate-to-severe anxiety, while 44% reported moderate-to-severe depression[7]. Mental health challenges hinder college student success as they impact motivation, concentration, and social interaction[2]. Longitudinal analyses showed that US college students who were depressed or anxious had significantly lower GPAs and higher risks of dropping out[8]. Diagnosed depression has been linked to a half a letter grade decrease in college GPA at one US university[9].

Certain groups of students are more likely than others to experience mental health problems. The most common risk factor is experiencing financial stress[10]. Gender and sexually diverse students tend to experience worse mental health outcomes than their majority group counterparts[11, 12]. Pre-pandemic, students from racial/ethnic minority backgrounds reported lower rates of diagnosed mental health problems and symptoms as compared to their White peers[13]. Since COVID-19 began, students from some racial/ethnic minority groups in the US have seen larger increases in mental health problems than White students, e.g., Black students with depression[14] and American Indian/Alaskan Native students with depression and anxiety[15]. Asian Americans have experienced spikes in depression symptoms relative to White Americans, partly

due to experiencing acute COVID-19 related hostility and discrimination at rates that are two-fold those of Whites[16].

Some survey research has investigated if online learning due to COVID-19 increased mental health problems for college students and findings are mixed[17-20]. When comparing two cross-sectional data sets from Fall 2019 and April 2020, medical students in Kazakhstan had reduced prevalence of the depression and anxiety after transitioning from traditional learning to online learning during COVID-19[17]. During a second COVID-19 outbreak in July 2021, students at a medical university in Taiwan showed no significant increases in psychological distress and life stress between periods of in-person and remote learning[18]. In the year after COVID-19 began, one-third of students in online science classes at one large US university (n=2111) reported no change in anxiety between modalities, while 40% reported higher anxiety in online science courses vs. in-person science courses[19]. Results from a US national survey, conducted during the first six months of 2021, found that college students who were fully online had higher levels of psychological stress than those had hybrid schedules with both online and in-person classes[20].

In addition to demographics and learning modality, faculty mentors can influence the mental health of undergraduate students[21], although this has been under-examined in the literature. Faculty mentors can play a critical role in student development, as trusted sources of academic and psychosocial support and professional development; they can also be "door openers," connecting students to opportunities and supportive resources[22]. A few studies show that support from mentors results in better mentee mental health[21, 23, 24], one of which was conducted with undergraduate researchers[25].

Despite widespread concerns about college student mental health, little is known about mental health of undergraduates engaging in research. College students engaging in undergraduate research are an important subpopulation that is comprised primarily of STEM students. During 2022, 22% of college seniors in the US had participated in undergraduate research[26]; this matches the pre-pandemic participation rate from 2019[27]. Undergraduate research is a high impact practice[28] that can springboard students into research careers and graduate school[29-31]. Participation is associated with boosts in critical thinking, increased interaction with faculty, enhanced academic achievement and retention, greater science self-efficacy, and greater persistence to STEM degree completion[32-35].

While there are many benefits to participation, undergraduate research experiences can be academically and emotionally challenging, as well as quite stressful for students. Associated stressors include negative faculty mentoring and negative research environments characterized by mentor absenteeism and abuse of power, unequal treatment and favoritism, exclusion or harassment, and a lack of social support[36, 37]. Half of undergraduate researchers from research-intensive public universities in the US had considered quitting their position and one-fourth actually quit, often due to negative experiences in their lab or with their mentors[37].

Few articles have examined the mental health of undergraduate researchers. Two were published before COVID-19 emerged[38, 39] and two were conducted during the early months of the COVID-19 pandemic[25, 40]; all four focus on US students. The initial study utilized 35 in-depth interviews with life sciences undergraduate researchers who had depression[38, 39]. Students' depression affected their motivation, creativity, productivity, engagement, and concentration in research as well as their self-perceptions and social interactions with research team members in negative ways[38]. Most students did not reveal their depression to their faculty research mentor,

but when they did, they benefited from increased understanding and support[39]. The second study was a nationwide survey of undergraduate researchers administered in July 2020[25, 40]. Of those participating in research during Spring 2020, 63% reported at least mild anxiety and 73% reported at least mild depression[25]. Experiencing adverse events associated with COVID-19 increased students' depression and anxiety severity[25]. Those whose summer research programs were modified to run remotely in Summer 2020 had greater odds of anxiety than those whose programs were cancelled[40].

Building from previous studies of mental health among undergraduate researchers, we use data from the US National Science Foundation (NSF)-funded Mentor-Relate study to examine how mentorship, remote participation, and COVID-19 challenges shape the mental health of undergraduate students participating in NSF Research Experiences for Undergraduate (REU) Sites during Summer 2022. We frame this analysis with the student wellbeing model (SWBM)[41]. This study speaks to the growing interest in college student wellbeing at universities and among researchers and the need to recognize and interact with undergraduate students as whole humans in order to make undergraduate research experiences more inclusive and equitable[40].

Conceptual framework

Wellbeing is a multifaceted concept that can reflect factors in someone's life that contribute toward fulfillment[42]. The education community has been working to broaden conceptions of student wellbeing beyond test scores and attendance to include health, resilience, social support, relationships, and engagement[41]. Soutter et al.[41] offered their Student Wellbeing Model (SWBM) in order to advance understandings of the multifaceted nature of student wellbeing in a K-12 context. To date, the model has been adapted to higher education contexts in

a limited way e.g., [40, 43]. The SWBM has seven distinct yet interconnected domains that are fundamental to wellbeing[41]. Table 1 lists and defines the seven domains, and also illustrates how each domain relates to variables that we use in this study.

[Table 1 About Here]

Research question and contribution

In this paper, we ask the research question: How are mentorship (*Relating* domain), remote participation, and COVID-research challenges (*Functioning* domain) associated with depression and anxiety severity (*Feeling* domain)? In answering this research question, we contribute to the literature in several ways. First, more knowledge is needed regarding undergraduate researcher mental health, given the broader concerns about college student mental health and the stressful nature of the research process. Two, while faculty mentorship is the linchpin of undergraduate research experiences[44], we know little about how faculty mentorship relates to undergraduate researcher mental health. Third, the landscape of higher education, and undergraduate research in particular, has changed since COVID-19 first emerged in Spring 2020. We need more systematic understanding of how these changes relate to student wellbeing so we can be better prepared to cope with future disruptions. Here, we examine COVID-19 variables of interest, i.e., remote engagement and research challenges due to COVID-19. As many undergraduate research programs currently utilize a mix of in-person and remote elements, more knowledge is needed about how these programmatic choices impact participants, including their mental health. A previous study of mental health examined remote participation vs no participation[40], but comparisons of more vs less remote participation is more relevant to the current COVID-19 context. Fourth, this analysis provides a second application of the SWBM to

undergraduate research, emphasizing the *Relating* domain, which was not the focus of the previous application[40].

Materials & Methods

NSF REU Sites

The Mentor-Relate study was approved by IRB boards at two universities [*names masked for peer review*] (#152679; # 2223-0034). Mentor-Relate focuses specifically on NSF REU Sites. REU Sites are established when the NSF funds program directors through multiyear awards to create summer research experiences for undergraduate students. REU Site programs are designed to attract and integrate women, underrepresented minorities, persons with disabilities, veterans of U.S. Armed Services, and first-generation college students to meet NSF's goal to broadening student diversity[45]. REU Sites tend to consist of multiple research teams that conduct research in any NSF-funded area. The REU model involves assigning each student to a faculty-led research project, although students may also work alongside postgraduate researchers, lab technicians, and/or other undergraduate researchers. Students can participate in REU Sites at their home institution, but they often travel to other institutions for these experiences. Students receive a stipend, housing, meals, travel, lab space usage and professional development[45]. Research has shown that student participants further develop their science identity, gain cultural capital, and augment their learning[46].

Participant recruitment and data collection

All students included in the study were 2022 REU Site participants. Figure 1 provides an overview of the recruitment and data collection process. We recruited our participants into Mentor-Relate through their REU program director. In Spring 2022, we identified all active REU sites via the NSF REU webpage (n=957). We then invited all REU Sites to enroll in our study

that met our inclusion criteria (n=416): 1) operating in Summer 2022; 2) Summer 2022 would not be their first year to avoid capturing launch year challenges that might bias results; and 3) would still be operating in Summer 2023 as Mentor-Relate enrolled another cohort then. In total, 109 Sites responded to our invitation and 78 Sites ultimately participated. These 78 Sites were located in 36 US states, Washington DC, and Puerto Rico. According to data we collected from the program directors, participating REU Site programs ranged in length from 6-12 weeks and enrolled 8-10 students. The programs included were in the following disciplines: biological and life sciences (n=20), math and computer science (n=14), physical sciences (n=21), engineering (n=21), and social science (n=2).

[Figure 1 About Here]

In September 2022, we asked each program director to send out an email script inviting their Summer 2022 REU students to participate. All students were eligible to participate; there were no exclusion criteria. We also provided scripted reminder emails to be sent out after one week and two weeks. We provided program directors with lists of students who completed the survey on the day before the reminder was due to be sent, so that they could be removed from the reminder lists. To reduce risks of feeling coerced to participate, students were informed that their program director would never see their responses and that they could quit the study at any time without penalty. They were invited to participate a month or so after their REU program had already ended, when their program director no longer supervised them.

Prior to launching the survey, we programmed it in Qualtrics and piloted it with undergraduate and graduate researchers (n=12) to gather feedback on the questions, length, and flow. We opened the Qualtrics survey on 28 September 2022 and closed it on 19 October 2022. Students consented to participate online and received a $20 Amazon gift card. The median time

to complete the survey was 29.8 minutes. Ultimately, we received complete/nearly complete data from 518 students attending 78 different programs. Given that 658 students clicked on the survey link, we estimate the cooperation rate to be 78.7%. We filtered out cases missing five or more of the analysis variables, leaving *n*=516 for analysis in this paper.

Participants

The participants are a diverse group of college students. In terms of their racial/ethnic breakdown, 46% are non-Hispanic White, 19% are Hispanic/Latino, 14% are Asian, 8% are Black, and the remaining 13% are from other non-White racial backgrounds. A small percentage are international students (3.5%). Over one-third (35%) are LGBQ+; 58% are women and 6% are non-binary. In terms of their socioeconomic status, the median personal income for the participants is <$15,000 and the median for parental income is $75,000-99,999. Just under one-third (29%) are first generation college students. They are a high achieving group, with the median GPA being 3.8, with a range of 2.1 to 4.0. The minority are first year students (9%) and the majority are juniors and seniors (41% and 22% respectively). They have a range of STEM majors, but nearly one-third are majoring in the life sciences. In terms of research type, 59% did lab research, 65% did computer or math research, and 21% reported conducting field work (many reported engaging in more than one type).

Dependent variables (feeling domain)

We examined depression severity and anxiety severity. For depression, students took the self-administered Patient Health Questionnaire (PHQ-9)[47, 48]. Each of the nine PHQ-9 sub-items are scored as integers from 0 ("not at all") to 3 ("nearly every day") and then summed to create a severity measure[48]. The summed variable had high internal consistency (α =0.875). For anxiety, we used the self-administered 7-item Generalized Anxiety Disorder Scale (GAD-7)[49], which is

one of the most widely used instruments for screening for anxiety disorders [50] due to its reliability[51] and validity[49]. As with the PHQ-9, the seven GAD-7 items are scored from 0 ("not at all") to 3 ("nearly every day") are summed to create a severity measure. The scale had high internal consistency (α=0.888). Table 2 reports univariate statistics for these dependent variables, as well as each other variable used in the analyses. Justification for classifying depression and anxiety as *Feeling* variables is included in Table 1.

Focal independent variables (relating & functioning domains)

The focal independent variables in the *Relating* domain are faculty mentor competency and having post-graduate mentor; the justification for them as *Relating* variables is in Table 1. All students had a faculty mentor and we asked them to complete the 26-item mentor competency assessment (MCA) for their faculty mentor. The MCA is a validated measure designed for undergraduate students in science fields to rate their research mentors' skill in six main areas: communication, managing expectations, gauging students' understanding, helping students develop independence, promoting diversity, and providing professional development training and opportunities[52]. For each of the 26 items, students rated their mentor from 1 ("not at all skilled") to 7 ("extremely skilled"). MCA scores are calculated by averaging responses across the 26 items (α=0.984). We also calculated subscale scores by averaging items pertaining to each of the six areas. Previous research has found mentoring competency based on MCA scores to correlate with graduate school intentions[53], research program satisfaction and science identity[54], and research gains[55]; it has not yet been associated with mental health outcomes.

We asked students if they worked closely with any postgraduate mentors or not. Postgraduate mentors were defined as graduate students or postdoctoral fellows. In some REUs, postgraduate mentors work alongside undergraduate students with shared faculty mentors.

Undergraduate students have reported that their postgraduate mentors are a source of help with research and that they provide insight into graduate school, serve as role models, and help the undergraduates to become more independent researchers; less often, they enforce a sense of hierarchy and have unrealistic expectations[56]. How postgraduate mentors influence undergraduate student mental health is not yet known.

The focal independent variables in the *Functioning* domain are remote research, remote meetings and COVID-related challenges; Table 1 provides justification for each as a *Functioning* variable. We asked students to report the percentage of remote time for a variety of activities during Summer 2022. These activities included "research," "meeting with mentors," "meeting with other members of research team," "meeting with other members of the REU program," and "attending workshops or trainings." We summed the percentages for the four meeting and workshop variables. We then recoded each the two continuous variables (i.e., percentage of time in remote research and in remote meetings/workshops) to determine if the student did this for ≥25% of the time or not. We used a ≥25% cutoff as it was a natural break in the data that captured a meaningful amount of remote engagement. Remote engagement is an important *Functioning* variable as it is now a common feature of higher education. Even as COVID-19 restrictions have eased, some interactions in higher education contexts (e.g., meetings) have remained remote. While we know that being fully remote during Summer 2020 was associated with greater depression symptomology among students[40], we do not know if a more limited amount of remote engagement during summer research influences undergraduate participants' mental health.

We asked students, "did you face any challenges caused by COVID-19 that affected your ability to conduct research during your 2022 REU?". Student responded Yes or No. We asked

this because previous research conducted in July 2020 found that COVID-19 related challenges were associated with more severe anxiety and depression among undergraduate researchers[25]. We do not know if COVID-19 related experiences still impacted undergraduate researchers' mental health as of 2022.

[Table 2 About Here]

Control variables

Justification for placing each control variable in each SWBM domain is provided in Table 1. In the *Having* domain, we used two variables related to academic standing. They are self-reported classification (i.e., junior, senior, and freshman/sophomore/unclassified [reference category]) and major (i.e., engineering; math, computer science, or physical science; other major, and life sciences [reference]). The variables in the *Being* domain are sociodemographic indicators as well as pre-existing mental health issues. We coded race/ethnicity into two categories (i.e., Hispanic and non-Hispanic Black, Asian, Native American, Native Hawaiian, Pacific Islander, or Multiracial and Other race [i.e., BIPOC] vs non-Hispanic White). We operationalized first-generation student status (vs. not) based on neither of the parents having earned a Bachelor's degree. We used parental income in three categories (<$60,000, $60,000-$149,000, and ≥$150,000 [reference]). We examined gender in three categories: man [reference], woman, and non-binary, as well as LBGQ+ status (gay, bisexual, lesbian, pansexual, asexual or other sexuality vs. not). We asked about lifetime prevalence of a psychological disorder (e.g., anxiety, depression, PTSD) vs. not. In the *Thinking* domain, we included previous research experience. We summed semesters and summers of previous research experience, prior to Summer 2022. Finally, in the *Striving* domain, we assessed students' level of agreement with the statement "This REU experience has helped you clarify your future career plans" on a scale of 1

("strongly disagree") to 6 ("strongly agree").

Analysis approach

We ran two sets of multivariable generalized estimating equations (GEEs)—one for each dependent variable—in IBM SPSS Statistics 25. We used GEEs as they extend the generalized linear model framework to treat clustered data[57] and our students were clustered in their REU programs. While we examined students in 78 REUs, some students wrote in their REU's name instead of selecting it from the drop-down menu provided in the survey. In some cases, those write-in responses were too general (e.g., Physics REU) to enable coding into the correct REU and so we coded these students into their own cluster. GEE models utilize an intracluster correlation matrix that we specified as exchangeable, which assumes constant intracluster dependency[57]. To select the best fitting models, we tested normal, gamma, and inverse Gaussian distributions with logarithmic (log) and identity link functions[57]. We used Inverse Gaussian with log link for both models reported here, as it was the best fitting combination of distribution and link functions. Results from the GEEs are not affected by multicollinearity based on tolerance and variance inflation factor criteria[58].

We report pooled results from multiply imputed data, which take into account the uncertainty associated with the missing values by penalizing the standard errors[59]. We used multiple imputation (MI) because missingness across one's variables can reduce sample size, statistical power and precision, as well as introduce bias if the values are not missing completely at random[60]. Information about missingness in each variable is presented in Table 2. MI involved using a regression-based approach to create multiple sets of values for missing observations [61]. We created 20 multiply imputed datasets, each with 200 iterations, and the imputed values at the maximum iteration were saved to the imputed dataset[61].

The first set of models includes the focal independent variables, with the exception of the MCA subscales, and the control variables. In the second set of models, which include the focal and control variables (but not the MCA composite), we disaggregated mentor competency into the six subscales to examine which ones were most closely related to depression and anxiety severity. This involved running six additional models for each dependent variable using the same specifications described above. We entered each subscale into a different model due to collinearity between the subscales.

We determined that we are adequately powered to run these models with our sample size of n=516 students. With a statistical power level of 0.8, 20 predictors, and a probability level of 0.05, we require a sample size of 122 to detect an effect size of 0.2—a "small" effect as per Cohen's classification[62].

Results

Table 3 reports results from the first set of models. Within the *Relating* domain, we found that more competent faculty mentors were associated with reduced depression severity. Each point higher on the MCA was associated with 2.0% drop in depression severity (p<0.05). The association was in the same direction for anxiety severity, but not significant (p<0.37). Not having a postgraduate mentor was positively, but not significantly, related to both outcomes, although the finding approached significance for anxiety (p<0.06).

Within the *Functioning* domain, we found that students who spent ≥25% of their time doing remote research or ≥25% of their time having remote meetings and workshops had 9.4% and 9.3% greater depression severity, respectively (both p<0.05). For anxiety, remote research was associated with a 7.9% increase in anxiety severity (p<0.05); findings for remote meetings did not approach significance. Students reporting that they had a COVID-19 challenge that

impacted their research experience was associated with 12.5% increase in depression severity (p<0.001) and 6.6% increase in anxiety severity (p<0.05).

In terms of the other variables, those in the *Being* domain were most salient across both outcomes. Pre-existing mental health challenges (both p<0.001) and non-binary identity (both p<0.05) were associated with greater depression and anxiety severity. BIPOC students had greater depression severity relative to non-Hispanic white students (p<0.05), as did LGBQ+ students relative to non-LGBQ+ students (p<0.01). Low-income students had greater depression severity than high-income students (p<0.05). Women had greater anxiety severity than men (p<0.05). In the *Thinking* domain, an additional unit of research experience (i.e., summer or semester) was associated with greater anxiety severity (p<0.05). None of the *Having* or *Striving* variables were statistically significant.

[Table 3 About Here]

Table 4 reports results from the second set of models including the MCA subscales in place of the MCA composite alongside all the other covariates from the first set of models. For depression severity, we found that the increases on the independence subscale and the professional development subscale were significantly related to decreasing depression severity such that a point increase on each scale was associated with a 2.3% drop (p<0.05) and a 1.7% drop (p<0.05) in depression severity, respectively. None of the subscales were significantly related to anxiety.

[Table 4 About Here]

Discussion

In terms of answering our research question, we found that reduced faculty mentor competency, remote participation and COVID-research challenges were associated with worse

mental health, with stronger associations for depression vs. anxiety. These factors are related to student wellbeing as they capture how students *Relate*, *Function*, and *Feel* during their summer REU. Emphasizing student wellbeing in undergraduate research programs is critically important, especially given the negative experiences that can occur for students in these contexts[36, 37]. A focus on wellbeing emphasizes the need to recognize and interact with undergraduate students as whole humans and to ensure that they are able to thrive and flourish in their lives. Others have noted that COVID-19 has "shifted the student wellbeing domain considerably due in part to the extensive pragmatic changes that have been introduced to curb the spread of COVID-19"[42, p. 6] and so studies of student wellbeing post-2020 provide important knowledge that can help universities, and undergraduate research programs in particular, plan for future disruptions.

The *Relating* element of wellbeing emphasizes the importance of connecting with others. In undergraduate research contexts, students form important relationships with their faculty mentor. We found that students who rated their faculty mentor more highly in terms of their mentoring competence had lower depression severity. This suggests that faculty mentors may have an important role to play in their trainees' psychosocial wellbeing. Others have found similar results relating mentoring to better emotional wellbeing[21, 24, 25]. For example, social support from faculty mentors during Spring 2020 research experiences at US universities was protective against more severe depression, but not anxiety[25].

In terms of why more competent mentors may buffer students against more severe depression, it is possible that competent mentors help students who suffer from depression better cope with failure and fears of failure. We know from other studies that STEM students with depression tend to have difficulties coping with failure[38]. Research on undergraduate researchers specifically has noted the fear of failure as an emotional cost of participation[63]. The "promoting

366 independence" subscale in the MCA, which was significantly associated with reduced depression
367 here, seems to capture mentoring actions that would buffer students from fear of failure, e.g.,
368 motivating mentees, instilling confidence, and nurturing their creativity. We also found that
369 students who reported that their mentors emphasized "professional development" were less
370 depressed. This MCA subscale relates to career goals, work/life balance, role models, and
371 obtaining resources. The subscales that were not significantly related to depression severity
372 emphasized skills and knowledge (understanding), communication, expectations, and diversity.
373 Interestingly, those domains are more internal to the research process while independence and
374 professional development are more outward looking. This dovetails with Saw et al.'s[21] finding
375 that instrumental mentoring (e.g., focused on mid-to-long-term goal attainment) boosted
376 students' mental health. Taken together, it appears that mentors who emphasize the big picture
377 with their mentees are promoting student wellbeing and reducing depression severity.
378 Spending ≥25% of one's research time during an REU on remote research and having
379 ≥25% of one's meetings/workshops remote were significantly related to elevated depression.
380 Remote research was also significantly associated with elevated anxiety. While few studies have
381 focused on mental health in remote research contexts, during Summer 2020, students
382 participating in remote summer research programs had greater anxiety severity than those whose
383 programs were cancelled[40]. We believe that these findings could be a cautionary message about
384 the potential risks of planning too much remote engagement with mentees during summer
385 research programs, although more research is needed. It is important to note that depression and
386 anxiety are just one endpoint. We do not know how remote engagement (vs. face-to-face contact)
387 relates to other student outcomes (e.g., research gains, satisfaction, science identity), but these
388 mental health outcomes are critical to student wellbeing. While remote engagement has benefits

389 (e.g., flexibility, opportunities to care for dependents while working)[64], our findings highlight
390 potential risks.

391 In terms of why remote engagement in Summer REU programs might be associated with
392 worse mental health, we can borrow some insight from studies of online science courses.
393 Research at a US university has revealed that online science courses are challenging for students
394 with mental health problems[19, 65]. Students with depression struggle with effort, focus, and time
395 management. The fast pace, lack of in-person contact, and difficulty forming relationships with
396 peers exacerbates depression symptoms[65]. Needing to be physically present in class provides
397 motivation for students with depression to engage, even though being physically present in class
398 is difficult during a major depression episode[65]. These factors related to online learning likely
399 extend to online research experiences. In terms of anxiety, science students report having greater
400 anxiety online than they do in-person because it is difficult to learn independently, stay engaged,
401 be organized, and to make connections with other students[19]. Importantly, science students with
402 depression report that one comforting aspect of online courses is that it is easier to ask questions
403 and receive answers[65]. By extension, it is plausible that the ease of having questions answered in
404 remote group contexts (e.g., by posting in chat instead of asking in front of a large group) is a
405 potential explanation for the insignificant association between remote meetings and workshops
406 during REUs and anxiety severity. Given the limited research to date on remote research
407 experiences and mental health, more studies are needed to draw definitive conclusions about this
408 topic.

409 Finally, we found that students whose REU was disrupted by COVID-19 experienced
410 elevated depression and anxiety symptoms relative to when their REU experience was not
411 disrupted by COVID-19. Similar findings emerged from a survey done in July 2020[25]. Our

findings reflects the reality that while many operate as if we are in a post-COVID-19 world, COVID-19 still presents challenges. Among students surveyed about Summer 2022, 37.5% of those reporting that COVID-19 impacted their research experience tested positive for COVID-19 themselves during the summer REU, and 30.4% had their REU disrupted by a close friend or family member falling sick. Since ~90% of the students were conducting research at another institution, it means that the vast majority of those struggling with COVID-19 were away from home when these COVID-19-related challenges emerged, which could have contributed to their anxiety and depression. These sorts of challenges associated with COVID-19 have been documented among college students worldwide[66, 67]. In addition, COVID-19 infection is a risk factor for anxiety and depression in the general population[68].

Limitations

The Mentor-Relate survey is missing some covariates that are relevant to college student mental health, e.g., parental depression, past experience with sexual harassment, parental separation[69], substance use, sleep problems, and a lack of physical activity[10]. The anxiety and depression measures pertain to the students' everyday lives and are not specific to their research experiences. While we launched the survey approximately one month after REUs ended, it is possible that events in the students' lives during those weeks influenced their responses to the GAD-7 and PHQ-9. Additionally, selection bias is possible as we do not know why some students did not respond to the survey. Those with the most serious mental health problems may have been less likely to participate in the survey.

Our analysis demonstrates associations between variables, but not causality. With these cross-sectional statistical methods, we cannot know if remote engagement causes depression symptoms or if students with depression symptoms are more likely to see out remote research

contexts. We also rely on student-reported measures of mentor competency, which could be influenced by symptoms of depression.

When studying remote research engagement, the quality of interactions—which we did not gauge—may be an important moderator of associations between remote engagement and outcomes. We also do not know why students were engaging in remote research (e.g., if they requested that modification or if it was part of their programs' design). The vast majority of our participants reporting remote engagement were participating in hybrid programs; only six reported that their REU was 100% remote. This makes our findings about remote engagement relevant to hybrid programs. Future research should examine outcomes among students in hybrid vs. fully remote programs.

Conclusion

Using a wellbeing framework, this study identified several factors that were associated with worse mental health among undergraduate researchers. We found that lower faculty mentor competency, substantial remote participation, and COVID-research challenges were associated with worse mental health, with stronger associations for depression vs. anxiety. The results give rise to several practical implications for research program directors, staff and faculty.

1. Seek to boost mentor competency

Findings suggest that improving mentor competency could possibly reduce depression symptoms among students in REUs. Encouraging mentors to attend mentor training is one way to improve competency. If mentor training is not offered at the institution, program directors can facilitate training by following a curriculum themselves, e.g., the validated "Entering Mentoring"[70]. Fostering mentors' skills specifically with helping students gain independence and with professional development, such as helping students see how their research extends

beyond the scope of their summer REU, may be helpful. This could be incorporated into mentor training. Since lab research tasks given to undergraduates can be repetitive and/or frustrating at times, mentors can help students understand how their current tasks contribute to the broader project and help students to see how they can use their findings to present at a conference. Future revisions to mentor training curriculum could emphasize mentee wellbeing more directly.

In addition, rewarding high quality mentoring and encouraging mentors to prioritize student development, given their many competing demands, are important. We know that faculty are less interested in mentoring when it is at odds with their institution's reward structure, and more interested when they see it as a pathway to increasing diversity within the academy[44]. While not currently allowed in many funded training programs in the US (e.g., NSF REUs), paying faculty mentors summer salary could help to recognize their efforts. Programs could also institute mentor awards programs to nominally recognize outstanding mentorship and/or create communities of practice where mentors can share advice and concerns.

2. Carefully consider remote engagement practices during summer research programs.

We found that remote engagement both in terms of research and meetings was associated with worse mental health, even accounting for mentor competency. Across higher education, substantial numbers of courses and programs are being conducted remotely or with remote elements. While remote engagement offers important accessibility and flexibility benefits, this may not always translate into improved wellbeing. Any concerns about remote engagement and mental health must be balanced against physical health risks associated with in-person contact, e.g., risk of COVID-19 transmission during the pandemic. Others have reflected on the strengths of engaging in remote (virtual) research mentoring, which include accommodating busy schedules, "chatting" during videoconferences, opportunities for immediate information

provision (e.g., screen sharing and posting links in chat), inclusion of people from distant places, and the ability to teach research techniques while screen sharing[64]. However, drawbacks include the need for a stable internet connection and working technology, lack of ambience, discomfort with sharing backgrounds, and intimidatation[64]. Students also report challenges with their ability to focus, learn, and feel successful in online courses in comparison to in-person ones[65].

Despite limitations, remote engagement is sometimes necessary. During those times, following recommended practices may help to improve mentees' experiences. These include using web cams with everyone setting virtual backgrounds to avoid discomfort and distraction, having mentees set the agenda, and beginning with small talk to break the ice. Since it can be harder to maintain motivation and team cohesion in remote research/mentoring contexts, mentors need to make extra efforts to support group unity, e.g., having "play-centric meetings" that are not focused directly on work[64]. Pfund et al.[71, p. 5] summarized their recommendations to mentors engaging in remote mentorship by saying, "be kind, do not make assumptions, ask questions, actively listen to the answers, and offer understanding and flexibility". Whether the mentor is meeting with their student in-person, or remotely, it is essential that "mentors prioritize attending to the well-being and humanity of their mentees as they facilitate their research and professional development"[71, p. 4].

3. Scaffold a support system into summer research programs to enhance student wellbeing.

Program directors, staff and faculty mentors can support students' *Functioning* by reducing stressors in the learning environment, integrating social interaction, improving access to resources and services[72], and fostering a sense of belonging[73, 74]. We believe that incorporating a social safety net into summer research programs by design could help to achieve this. This safety net could include peer mentoring, multiple research mentors, team-based research with other

undergraduates, and organized activities. Since REU students are usually away from their home or home institution during the summer, this sort of local support could be beneficial. As having one's research disrupted by COVID-19 related to increased risk of depression and anxiety during Summer 2022, the post-2020 research landscape requires that we pay special attention to signs of loneliness and isolation in students[75]. Since students may need or want to distance themselves, this social safety net can ensure they remain connected. Mental health concerns disproportionately affect the wellbeing of women, non-binary and LGBQ+ students, and students of color and they additionally may have greater difficulties coping with COVID-19 related stressors[76]; thus further underscoring the need for inclusive social safety nets. Research mentors can also proactively inquire about student wellness, asking questions like: "Do you have a positive strategy to handle stress?"; "How might I support your self-care during this time?"; and/or "What support resources are available to you?" They can direct mentees to wellness resources, e.g., those available at the US National Institutes of Health Office of Intramural Training and Education web page[71]. By addressing emotional wellbeing in a higher education context through promotion of inclusivity and equality and practices that proactively address mental health, we hope that students will be able to engage in educational experiences that allow them to thrive and flourish.

Final Note

If you or someone you know is struggling with depression or anxiety, please visit the website of your university health center. In the US, national mental health helplines and websites also provide advice on managing depression and anxiety, e.g., Substance Abuse and Mental Health Services Administration (1-800-662-HELP) and the National Alliance on Mental Illness (1-800-950-NAMI or www.nami.org/help/)[19].

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Figures and Tables

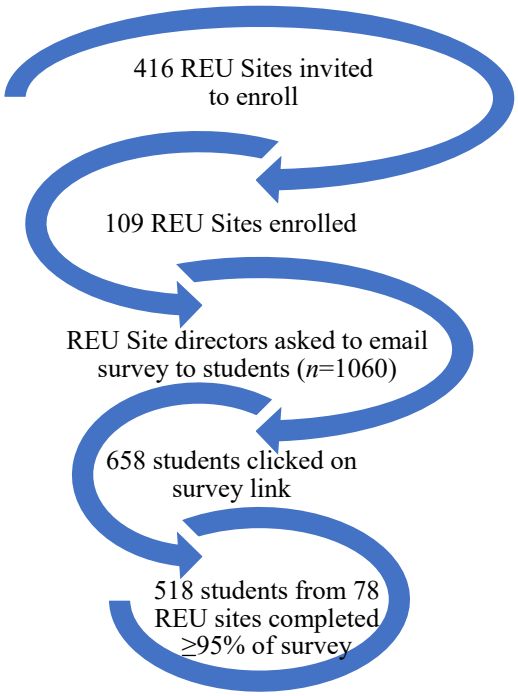

Figure 1. Participant Recruitment and Data Collection for Mentor-Relate Student Survey

534 **Table 1**. The domains in the Student Well-Being Model and associated variables used in this
535 analysis

Domain	Description	Variables related to REUs by domain with references supporting their applicability	Justification for variable assignment by domain
Relating	Emphasizes relationships and interpersonal connections	• Has post-graduate mentor • Faculty mentor competency	• Because the number of mentors/team members, interactions with mentor(s), and mentor competency reflects interpersonal connections during SUREs
Functioning	Includes how students engage in educational experiences	• Engaged in remote research and remote team meetings and workshops • Any COVID-related research challenges[77]	• Because remote REU activities change the nature of the engagement in the experience • Because research challenges due to COVID-19 shape student engagement.
Having	Relates to what the students' have gained through their time in college (e.g., resources and opportunities)	• Classification (e.g., senior)[30]. • GPA[35, 78]	• Because college credits earned and GPA reflect an accumulation of learning
		• Academic major[27]	• Because students gain knowledge in their major area
Being	Relates to the conditions of students' lives and their identities	• Race/ethnicity[79-81] • First generation status[82] • Parental income[82] • LGBQ+ identity[83] • Gender[79, 84, 85]	• Because race/ethnicity, first-generation student status, socioeconomic status, sexuality, gender, family income, international student status and high school achievement are important elements of college student identity.
		• Pre-existing mental health conditions[38, 39]	• Because pre-existing mental health conditions can shape sense of self.
Thinking	Includes opportunities to be	• Prior research experience	• Because longer duration research opportunities,

	creative and actively engaged in cognitive tasks	(semesters of research) and location of SURE[86, 87]	especially in multiple places, can lead students to cultivate a nuanced understanding of the factors that comprise a research environment and they have more opportunities to engage in research tasks.
Feeling	Includes the emotional component of well-being	• Anxiety and depression severity[25]	• Because mental health severity metrics capture how students feel during their REU experience.
Striving	Captures students' future goals and their abilities to stay motivated to achieve those goals	• REU helps to clarifies future plans	• Because how the REU contributed to their thinking about the future captures their future goals.

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Table 2. Descriptive Statistics (*n*=516)

	Min.	Max.	Mean	SD	Yes (*n*)	No (*n*)	Missing (*n*)
Relating							
Faculty Mentor Competency Assessment (MCA)	1.04	7	5.726	1.314			22
Communication subscale	1	7	5.795	1.323			9
Expectations subscale	1	7	5.771	1.419			8
Understanding subscale	1	7	5.779	1.397			8
Independence subscale	1	7	5.736	1.395			10
Diversity subscale	1	7	5.733	1.391			6
Professional Development subscale	1	7	5.532	1.474			7
No postgraduate (PG) mentor					287	229	0
Functioning							
Remote Research (≥25%)					65	451	0
Remote Meetings and Workshops (≥25%)					42	475	0
COVID-19 research challenges					99	416	1
Having							
First/Second Year (reference)					191	324	1
Junior					211	304	1
Senior					113	402	1
Life Sciences Major (reference)					146	363	7
Engineering Major					111	398	7
Math/Computer Sci/Physical Sci Major					214	295	7
Other Major					38	471	7
Being							
Pre-existing psychological problems					148	360	8
First generation status					147	365	4
Low parental income (<$60K)					155	345	16
Mid parental income ($60K-149,999)					231	269	16
High parental income (≥$150K) (reference)					114	386	16
BIPOC student					276	235	5
LGBQ+					178	331	7
Man (reference)					181	328	7

Woman					297	212	7
Non-binary					31	478	7
Thinking							
Units of previous research (i.e., summers or semesters)	0	8	1.38	1.707			2
Striving							
REU helped clarify future career plans	1	6	5.21	0.978			1
Feeling (dependent variables)							
Depression Severity (PHQ-9 Sum)	0	27	5.591	4.787			7
Anxiety Severity (GAD-7 Sum)	0	21	5.322	4.487			7

Table 3: Pooled results of generalized estimating equations (GEEs) predicting depression [PHQ-9 sum score] (A) and anxiety [GAD-7 sum score] (B) severity (*n*=516 Summer 2022 REU participants)

	A					B				
	b	Lower CI	Upper CI	exp(B)	*p*	b	Lower CI	Upper CI	exp(B)	*p*
Intercept	2.661	2.460	2.861	14.305	***	2.556	2.350	2.762	12.883	***
Relating										
Faculty MCA	-0.021	-0.041	-0.0000007	0.980	*	-0.008	-0.026	0.010	0.992	
No PG mentor	0.025	-0.021	0.072	1.026		0.046	-0.001	0.094	1.047	`
Functioning										
Remote Research (≥25%)	0.091	0.012	0.169	1.095	*	0.076	0.009	0.143	1.079	*
Remote Meetings and Workshops (≥25%)	0.089	0.009	0.170	1.093	*	-0.005	-0.067	0.058	0.995	
COVID-19 research challenges	0.118	0.064	0.171	1.125	***	0.063	0.007	0.120	1.066	*
Having										
First year/sophomore (ref)										
Junior	-0.020	-0.069	0.029	0.980		-0.027	-0.077	0.023	0.973	
Senior	-0.020	-0.085	0.045	0.980		0.0005	-0.056	0.057	1.000	
Life Sciences Major (ref)										
Engineering Major	0.014	-0.040	0.068	1.014		0.008	-0.040	0.055	1.008	
Math, Comp Sci, Physical Sci Major	0.028	-0.020	0.077	1.029		0.021	-0.029	0.071	1.021	
Other Major	-0.011	-0.091	0.070	0.990		0.010	-0.061	0.081	1.010	
Being										
Pre-existing psychological problems	0.211	0.154	0.267	1.234	***	0.190	0.129	0.251	1.209	***
First generation status	-0.004	-0.056	0.048	0.996		0.011	-0.038	0.060	1.011	
High parental income (ref)										
Low parental income	0.069	0.006	0.133	1.072	*	0.045	-0.015	0.104	1.046	
Mid parental income	0.030	-0.020	0.081	1.031		0.042	-0.009	0.093	1.043	

LGBQ+	0.059	0.013	0.105	1.061	*	0.025	-0.024	0.074	1.025	
BIPOC	0.044	0.005	0.083	1.045	*	-0.003	-0.045	0.039	0.997	
Man (ref)										
Woman	0.011	-0.038	0.060	1.011		0.068	0.016	0.120	1.070	*
Non-binary	0.126	0.022	0.231	1.135	*	0.130	0.021	0.239	1.139	*
Thinking										
Units of previous research	0.004	-0.007	0.016	1.004		0.013	0.000	0.027	1.014	*
Striving										
REU helped clarify future career plans.	-0.005	-0.032	0.022	0.995		0.001	-0.030	0.031	1.001	

Notes: Models report pooled results of 20 imputed data sets. Models use inverse Gaussian with log link, an exchangeable correlation matrix, and control for clustering at the REU program level. Since PHQ-9 and GAD-7 scores have 0 values, we added a constant so we could use Inverse Gaussian distribution, which fit better than normal (which allows zero values). *** $p<0.001$, **p<.01, *p<.05, `p<.10

Table 4. Pooled results of generalized estimating equations (GEEs) predicting depression [PHQ-9 sum score] (A) and anxiety [GAD-7 sum score] (B) severity, looking at the independent effect of each MCA subscale (*n*=516 Summer 2022 REU participants)

	A					B				
	b	Lower CI	Upper CI	exp(B)	*p*	b	Lower CI	Upper CI	exp(B)	*p*
MCA: Diversity	-0.014	-0.031	0.004	0.986		-0.001	-0.018	0.017	0.999	
MCA: Communication	-0.017	-0.036	0.003	0.984	`	-0.007	-0.024	0.011	0.993	
MCA: Understanding	-0.017	-0.037	0.002	0.983	`	-0.010	-0.027	0.007	0.990	
MCA: Expectations	-0.016	-0.036	0.004	0.984		-0.006	-0.023	0.011	0.994	
MCA: Independence	-0.024	-0.042	-0.005	0.977	*	-0.009	-0.025	0.007	0.991	
MCA: Professional Development	-0.018	-0.035	-0.000	0.983	*	-0.009	-0.024	0.006	0.991	

Notes: Models report pooled results of 20 imputed data sets. Models use inverse Gaussian with log link, an exchangeable correlation matrix, and control for clustering at the REU program level. All models control for academic classification, major, pre-existing mental health conditions, first-generation status, parental income, LGBQ+ status, race, gender, remote research, remote meetings and workshops, the presence of a postgraduate mentor, COVID research challenges, previous research, and future plans. We ran a model that include each of the MCA components separately (due to multicollinearity). As such, the table reports results from 12 models. *** $p<0.001$, **p<.01, *p<.05, `p<.10

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