INVESTIGATING TEST ANXIETY AND THE EFFECTS OF SUPPORTIVE MESSAGES

BY

ROBERT T. DELOATCH

DISSEbATION

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Computer Science in the Graduate College of the University of Illinois at Urbana-Champaign, 2017

Urbana, Illinois

Doctoral Committee:

Professor Alex Kirlik, Chair
Professor Brian Bailey, Director of Research
Professor Darren Gergle, Northwestern University
Associate Professor Chad Lane
Associate Professor Craig Zilles
ABSTRACT

Many students underperform on exams due to experiencing high test anxiety. In this dissertation, I present three studies examining how test anxiety affects students taking open-ended computer programming exams and methods to reduce it. In the first study, I conduct a survey to show the prevalence of test anxiety in computer science and the methods students use to cope with it. In the second study, I report on an experimental study comparing a novel intervention of seeking support from one’s own social network to the more common approaches of expressive writing and studying task-relevant materials for open-ended test questions. In the final study, I present an experimental study comparing how the perceived authorship of supportive messages affects the anxiety and performance of students completing open-ended programming questions. The results show that 23% of students experience high test anxiety when taking computer based programming exams and 22% of students have no method of coping with it. They also show that soliciting messages from social media can result in a 21% reduction in anxiety, an increase in testing performance, and the perceived author of these messages affects the magnitude of the decrease in anxiety. These studies have implications for students who take, instructors who write, and companies that use programming tests to evaluate new hires. I aim to demonstrate why test anxiety should be considered when designing or preparing for exams and how to integrate reduction strategies into the testing process.
To my family, friends, and mentors, your support made this possible.
ACKNOWLEDGMENTS

This dissertation would not have been possible without the guidance and mentorship of my advisors Professor Alex Kirlik and Professor Brian Bailey. They improved the quality of this work with their feedback throughout the planning and writing stages of this dissertation. Their financial commitment made it possible for me to present my work at conferences and to conduct experiments. They set examples of how to be strong researchers and instilled those qualities in me.

Thank you to Professor Craig Zilles’ who’s vision of the computer based testing center on campus allowed me to explore the domain of test anxiety in this setting. His financial support also helped for conducting experiments and traveling for conferences. Professors Chad Lane and Darren Gergle were instrumental in providing feedback for my preliminary exam and final dissertation. Their experience in computer science education and communication helped shaped the direction of my work.

The HCI group at UIUC helped provide the support and community to openly share ideas, solicit feedback, and grow into a researcher that embraced critique. Thank you Kristen Vaccaro, Yu (Wayne) Wu, and Yu-Chun (Grace) Yen for being there day-to-day to share ideas and lend advice.

The USER Group at IBM Research Almaden was instrumental in reshaping how I approached research, organization, and development. Thank you Liang Gou, Jeffrey Nichols, Chris Kau, and Michelle Zhou for mentoring me through my internship at IBM and reigniting my desire for user research.
My friends at UIUC, especially Ryan Musa and Daphne Tsatsoulis, thank you for your emotional support through this experience. Going through this experience with you made this much more enjoyable.

Thank you to the Meyerhoff Scholars Program at University of Maryland Baltimore County led by Mr. LaMont Toliver, Mr. Keith Harmon, Ms. Mitsue Wiggs, Ms. Earnistine Baker, Mr. Michael Goodwyn, Ms. Alicia Hall, and Ms. Sharon Hall. The mentorship, feedback, and community you all provided made graduate school a possibility. Thank you for your hard work and dedication to increasing the number of underrepresented minority doctoral students.

To my parents, Mr. Robert Deloatch and Karen Deloatch, thank you for the love and energy you put into me, instilling the desire to learn and work hard. You both have been my role models since I was a child. Thank you for being patient through my years of schooling and always providing support.

To my sister, Christine Deloatch, thank you for encouraging me and giving me advice through the low times and celebrating with me during the high times. You’ve been the best big sister a brother can ask for. Watching you grow, mature, and find success has always motivated me to do the same.

To my sons, Derek and Daniel, your love, joy, and compassion fueled me through the toughest times of this dissertation. You both brought new meaning into my life and I refocused on completing this dissertation because of you.

Thank you to my best friend, chief advisor, partner, role model, and wife Dr. Nicole Brown. You have accelerated my growth as a critical thinker, researcher, friend, and a father. Everyday you love and support me and this dissertation is complete because of you.
TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION ............................................................................................... 1
  1.1 SUPPORTIVE MESSAGES ......................................................................................... 2
  1.2 CONTRIBUTIONS .................................................................................................... 3
  1.3 OUTLINE ................................................................................................................... 5

CHAPTER 2: RELATED WORK ............................................................................................. 6
  2.1 METHODS OF ANXIETY REDUCTION .................................................................... 6
    2.1.1 Social Support ...................................................................................................... 6
    2.1.2 Expressive Writing .............................................................................................. 8
    2.1.3 Additional Methods ........................................................................................... 9
  2.2 FACTORS OF MESSAGES ......................................................................................... 10
    2.2.1 Message Authorship .......................................................................................... 10
    2.2.2 Message Content ............................................................................................... 10
    2.2.3 Other Factors ..................................................................................................... 11
  2.3 TEST ANXIETY ........................................................................................................ 11
    2.3.1 Theories of Test Anxiety ................................................................................... 12
    2.3.2 Measures of Test Anxiety ................................................................................ 13
    2.3.3 Anxiety and Open-ended Questions ................................................................... 14
    2.3.4 Modality and Test Anxiety ............................................................................... 15

CHAPTER 3: EFFECTS OF MODALITY OF PROGRAMMING-CENTRIC EXAMS .......... 16
  3.1 METHOD .................................................................................................................... 16
    3.1.1 Survey Description ............................................................................................ 17
    3.1.2 Survey Distribution ......................................................................................... 17
    3.1.3 Participants ....................................................................................................... 19
  3.2 RESULTS .................................................................................................................... 19
    3.2.1 Likert Responses .............................................................................................. 19
    3.2.2 Open-ended Responses .................................................................................. 22
  3.3 DISCUSSION ............................................................................................................. 25
    3.3.1 Implications ....................................................................................................... 25
    3.3.2 Limitations ......................................................................................................... 28
    3.3.3 Future Work ....................................................................................................... 29

CHAPTER 4: COMPARING ANXIETY INTERVENTIONS FOR OPEN-ENDED
PROGRAMMING PROBLEMS ................................................................................ 30
  4.1 METHOD .................................................................................................................... 31
    4.1.1 Participants ....................................................................................................... 31
    4.1.2 Tasks .................................................................................................................. 32
    4.1.3 Anxiety Interventions ..................................................................................... 33
    4.1.4 Measures ......................................................................................................... 34
    4.1.5 Procedure ......................................................................................................... 35
  4.2 RESULTS .................................................................................................................... 39
    4.2.1 Effects on Anxiety ........................................................................................... 42
    4.2.2 Effects on Performance .................................................................................. 43
    4.2.3 Participant Perceptions .................................................................................. 44
  4.3 DISCUSSION ............................................................................................................. 48
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3.1 Implications</td>
<td>49</td>
</tr>
<tr>
<td>4.3.2 Limitations</td>
<td>51</td>
</tr>
<tr>
<td>4.3.3 Future Work</td>
<td>52</td>
</tr>
<tr>
<td>CHAPTER 5: PERCEIVED AUTHORSHIP EFFECTS ON ANXIETY AND PERFORMANCE</td>
<td>53</td>
</tr>
<tr>
<td>5.1 METHOD</td>
<td>53</td>
</tr>
<tr>
<td>5.1.1 Participants</td>
<td>54</td>
</tr>
<tr>
<td>5.1.2 Open-ended Problems</td>
<td>55</td>
</tr>
<tr>
<td>5.1.3 Supportive Messages</td>
<td>56</td>
</tr>
<tr>
<td>5.1.4 Procedure</td>
<td>60</td>
</tr>
<tr>
<td>5.1.5 Measures</td>
<td>62</td>
</tr>
<tr>
<td>5.2 RESULTS</td>
<td>63</td>
</tr>
<tr>
<td>5.2.1 Effects on Anxiety</td>
<td>64</td>
</tr>
<tr>
<td>5.2.2 Effects on Performance</td>
<td>67</td>
</tr>
<tr>
<td>5.2.3 Perceptions</td>
<td>69</td>
</tr>
<tr>
<td>5.3 DISCUSSION</td>
<td>72</td>
</tr>
<tr>
<td>5.3.1 Implications</td>
<td>73</td>
</tr>
<tr>
<td>5.3.2 Limitations</td>
<td>74</td>
</tr>
<tr>
<td>5.3.3 Future Work</td>
<td>75</td>
</tr>
<tr>
<td>CHAPTER 6: BROAD IMPACT</td>
<td>76</td>
</tr>
<tr>
<td>6.1 DISCUSSION</td>
<td>76</td>
</tr>
<tr>
<td>6.2 LIMITATIONS</td>
<td>81</td>
</tr>
<tr>
<td>6.3 FUTURE WORK</td>
<td>81</td>
</tr>
<tr>
<td>6.4 CONCLUSION</td>
<td>82</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>84</td>
</tr>
<tr>
<td>Appendix A: Pre-test questions</td>
<td>93</td>
</tr>
<tr>
<td>Appendix B: Programming Problems</td>
<td>95</td>
</tr>
<tr>
<td>Appendix C: IRB Approvals</td>
<td>100</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

Testing is used to make decisions about people. In college admissions, standardized tests are used to decide whether or not to admit a student, provide merit scholarships, and to place them in college courses. In courses, exams are administered to provide a reliable estimate of an individual’s aptitude and thus are often weighted heavily, accounting for sometimes half or more of a student’s grade. Admission and scholarship programs use standardized tests to measure student achievement or predict their future success [16]. However, research on test anxiety indicates that the information exams intend to capture, such as aptitude and future success, is made noisy by the pressure of the exam [86]. In these situations, a student’s anxiety causes them to perform worse than their ability when compared with less pressured situations. When the consequences of poor performance on tests are high, ranging from losing educational and financial opportunities to causing psychological distress and ill health, it becomes critical that tests measure what they intend.

Furthermore, the prevalence of test anxiety is cause for concern. With studies reporting approximately 25% of students suffering from test anxiety, researching methods to reduce it is a focus for researchers [45]. The most common approach for reducing test anxiety is systemic desensitization [86]. This method requires a trained professional working with a student over repeated sessions and requires the professional to construct a hierarchy of anxiety inducing situations for each student. The burden of time and personalization limits the generalizability of the approach. Additionally, students sometimes become overwhelmed immediately before the
exam neglecting to effectively apply the behaviors the procedure intends to instill. Recent research demonstrated that a seven minute writing task, where students write about their thoughts and feelings, before an exam can increase the score of students with high anxiety [65]. This work has been critical in demonstrating that performance of students can be improved without the aid of a trained therapist or previous training.

To reduce general anxiety, researchers have leveraged technology to design interventions. Previous work demonstrated how robots, virtual reality, and touch-sensitive games, and could be applied to reduce the anxiety of participants [60, 62, 82]. However, as most exams are administered on paper, integrating technological interventions into exams to combat test anxiety has yet to be applied. The adoption of computer based testing increased accessibility to technologically based anxiety interventions and in this dissertation I focus on these methods. Specifically, I show how technology can be leveraged to disseminate supportive messages to students before evaluative situations, reducing their anxiety and helping them perform their best.

1.1 SUPPORTIVE MESSAGES

Supportive messages are examined because they have demonstrated success in aiding performance. In the 1980s, Sarason, a leading researcher in studies of test anxiety, showed that students who overheard a supportive message directed toward another student before completing an anagram task, scored higher than students who did not overhear the message [70]. The effects of supportive messages on test anxiety were explored again when Kimbler showed that a supportive message could decrease the test anxiety of older adults and increase their scores on the Everyday Problem Solving Test [48]. Outside of test anxiety, researchers explored how phones and computers could be leveraged to provide supportive messages that influence human behavior. For example, researchers demonstrated that supportive text messages led to a reduction
in the number of alcoholic beverages hazardous drinkers consumed [79]. Additionally, encouraging messages provided on the computer improved the experience of players of an educational videogame [44].

In this dissertation, I show how instructors can integrate supportive messages into their testing process. I demonstrate how students can solicit supportive messages from their online social media network, and that reading the messages before an exam can reduce anxiety and increase performance on computerized exams with open-ended questions.

Also important is examining how the perceived authors of the supportive messages affect test anxiety. In other words, how does the believed source of a supportive message affect test-takers’ anxiety? This question has a rich history of being studied when examining questions of credibility for websites, newspaper articles, and product advertising. This literature shows that trustworthiness, expertise, and similar experiences affect people’s judgments of credibility even when the content provided is identical [9, 12, 36]. However, this question has yet to be explored in the domain of supportive messages. By comparing supportive messages written by peers with those written by family members, we can deepen understanding of how these messages affect test anxiety, performance, and provide an approach that can be scalable in practice. I investigate this and provide evidence for the effects messages written by peers and social media ties have on the anxiety and performance of students.

1.2 CONTRIBUTIONS

I make the following contributions in this dissertation:

1. **Expand knowledge of the prevalence of test anxiety in computer science and methods students use to cope with that anxiety.**
In Chapter 3 I describe a large-scale survey that examines the effects modality of programming-centric exams (computer- vs. paper-based) has on the perceived anxiety and performance of students. This chapter also surveys the coping strategies students’ use for programming-centric exams, and shows that 22% of students experience anxiety, but have no method of coping with it. This chapter also deepens understanding of the challenges, benefits, and preferences students report for each modality.

2. **Demonstrate the effectiveness of using social media for soliciting supportive messages for an anxiety intervention before exams.**

In Chapter 4, I describe a study focused on applying a novel method of social media to the reduction of test anxiety. It demonstrates that it is possible to solicit supportive messages from social media for a simulated-exam. It also shows how these messages can be used to reduce the anxiety high test-anxious students experience by 21% and increase their performance so they perform as well as low test-anxious students. In this chapter, I examine how this novel method compares to the more widely studied approach of expressive writing and I extend the literature of anxiety reduction to the domain of open-ended programming problems.

3. **Demonstrate how the perceived author of a supportive message influences their efficacy as an anxiety intervention.**

In Chapter 5 of this dissertation, I present an alternative approach to obtaining supportive messages. I describe a study demonstrating how the author of supportive messages affects the anxiety of students and their performance on open-ended tasks. I compare how anxiety is affected by the perception that messages originate from social media, peers with similar experience, and famous innovators. The results of the study show that
messages from social media and peers can reduce the anxiety of students. I discuss the implications acquiring supportive messages from social media and peers have for students and instructors. I also provide guidelines for instructors to use for integrating supportive messages into their testing process.

1.3 OUTLINE

In the next chapter, I present a deeper explanation of methods of anxiety reduction, how social media and technology have been previously applied, how the perception of message authorship affects behavior, and the related literature on test anxiety. In Chapter 3, I present the survey I applied to understand how modality effects anxiety and the coping strategies students apply. In Chapter 4, I discuss a study demonstrating the novel application of social media to anxiety reduction. In Chapter 5, I present a follow-up study exploring how perception of message authorship affects the interpretation of supportive messages and provide guidelines for how to integrate this intervention into the classroom. In Chapter 6, I discuss the implications this dissertation has for students, instructors, and theory, highlight future work, and conclude.
CHAPTER 2
RELATED WORK

I first situate the methods of anxiety reduction I apply within the literature. I then discuss previous work on how message factors, such as authorship, content, and medium affect behavior and present where this dissertation fills gaps in this literature. Finally, I present the studies of test anxiety, its measures, and how this dissertation contributes to the theory.

2.1 METHODS OF ANXIETY REDUCTION

Test anxiety reduction techniques can be split into four categories: optimizing procedures, emotion-focused methods, cognitive-focused methods, and skills-focused methods [86]. I focused on emotion-focused methods because they have demonstrated effectiveness for reducing anxiety and increasing performance on exams. Optimizing procedures require direct modification to the exam, such as changing exam style or allowing the use of notes. Cognitive-focused methods have demonstrated little reduction in anxiety without being used in conjunction with emotion-focused methods [86]. Skills-focused methods focus on study-skills training and have proven to be ineffective when used alone because many students with test anxiety possess good study habits. I use social support and expressive writing as emotion-focused anxiety reduction methods.

2.1.1 SOCIAL SUPPORT

Social support is defined as an “interpersonal transaction in which one can rely on others for information, help, and advice” [59]. It consists of several categories, including emotional
support (e.g. encouragement, sympathy, love), instrumental aid (e.g. providing material aid or behavior assistance), companionship (e.g. spending time with others during leisure time), and informational support (e.g. guidance) [73]. HCI researchers have examined the effects of social support in education. For example, Saerbeck and colleagues showed that a socially supportive robot helped children score higher on a language test and report higher intrinsic and task motivation than children in a neutral condition [68]. Kao and Harrell showed that an encouraging message, such as “You’re doing well,” shown while participants were playing a STEM learning game improved the experience of the game for players [44]. Other researchers in the HCI community have examined how social media is leveraged for support when experiencing life events, such as gender transition or job loss [15, 35]. Online health communities have also been investigated as a source of social support [54, 57, 84]. For example, Newman and colleagues studied how seeking social support in online health communities and social networks can provide emotional support, accountability, and motivation [57]. Wang and colleagues found that members of online health communities who receive emotional support participate longer than members receiving only informational support [84].

Researchers in the behavioral sciences have also studied the impact of social support on test anxiety. For example, Sarason showed that students who participated in either a group discussion or overheard a supportive message directed toward another student before completing an anagram task, scored higher than students who did not participate in the discussion or overhear the message [70]. These effects were even more favorable for high test-anxious students. Additionally, Kimbler showed that a single emotionally supportive message before completing the Everyday Problem Solving Test reduced the number of distracting thoughts participants experienced and increased task performance [48]. In this dissertation, I expand on
this research by developing a novel intervention for test anxiety reduction where students request social support by leveraging their online social network. Additionally, I demonstrate its effectiveness in the domain of open-ended problem solving. I chose to use social media as an intervention because it can be applied widely through technology and is familiar to students without the need for training or a professional.

2.1.2 EXPRESSION WRITING

Recently, Ramirez demonstrated that writing about one’s thoughts and feelings before arithmetic problems or an exam increased math accuracy and exam scores, respectively, for students when compared to students who were asked to think about task-irrelevant topics before the same evaluation [65]. The expressive writing task was shown to be especially beneficial for students with high test anxiety or high math anxiety [61, 65]. Additionally, Lang used a writing exercise to heighten student self-perceptions of their knowledge. The writing exercise increased the scores of high test-anxious high school students on an intelligence test, while lowering the scores of low test-anxious students [51]. This prior work shows that expressive writing can reduce student test anxiety on forced-choice problems.

I study expressive writing to extend prior work by demonstrating how it affects anxiety and performance of students solving open-ended problems. These problems have more uncertainty related to solution generation and have demonstrated to be viewed as more anxiety provoking than forced-choice problems [75, 86]. Additionally, I examine this problem in a computer-based setting where students develop computer programs with the use of coding tools. This setting can provide added feelings of anxiety from hearing the busyness of the lab with peers typing or receiving a list of compiler errors when code does not work [58].
2.1.3 Additional Methods

There are approaches for anxiety reduction beyond social support and expressive writing. Other emotion-focused approaches require working with a trained professional on relaxation and desensitization procedures [23, 74]. Hembree’s meta-analytic study found that these approaches reduce anxiety but found mixed results for increasing cognitive performance [38]. When combining emotion and cognitive-focused approaches, such as through cognitive behavior modification, researchers showed that the factors of test anxiety, worry and emotionality, could be reduced 0.82 and 0.73 standard deviations respectively. Additionally, this method raised grade point averages by 0.72 standard deviations [38]. Though effective, the high investment of cost and time make it best equipped for those experiencing the most severe forms of test anxiety.

Recently, approaches using technology to reduce general anxiety have been explored. For example, DEEP, a biofeedback virtual reality game, reduced the self-reported anxiety of children and helped better regulate their breathing [82]. Park and her colleagues demonstrated that by using a physical plant as a controller of a gardening game they could help reduce the anxiety of players [62]. Paredes and Chan showed how electronic wristbands could be used to send haptic feedback when people are anxious [60]. These methods required additional physical technology and had limited ability to scale for a larger number of students. I applied a novel use of social media to anxiety reduction by having people solicit messages from their private social media profiles. This method was applied without additional physical tools and could scale with more students. Additionally, I extended the application of technology for anxiety reduction to the domain of testing.
2.2 FACTORS OF MESSAGES

Factors of messages can affect how they are perceived. For example, the authors of a message and the message’s content are two factors previously studied in the literature. I discuss these and other factors below.

2.2.1 MESSAGE AUTHORSHIP

Previous work shows that who provides the content of a message can affect interpretation. For example, Birnbaum showed that participants rated the true values of used cars higher when estimates came from a friend of the potential seller, compared to a friend of the buyer or an independent person [9]. Hale showed that participants’ perceptions of accuracy differed for three news stories that were identical in content, but were attributed to different sources [36]. Additionally, Brownlow showed that facial appearances affected the perception of honesty, with baby-faced people being viewed as more honest when presenting the same information as non-baby-faced [12].

In this dissertation, I compare how three different message sources are perceived. I also examine how the authorship of the message affects perception of supportiveness, anxiety, and performance.

2.2.2 MESSAGE CONTENT

Studies investigating how message content affects perception often examine the factor in conjunction with changes in authorship making it difficult to tease apart effects. For example, Goldsmith and colleagues investigated how an individual’s peer support group affects their anxiety and performance when compared to their out of class support group [32]. They showed students with high test anxiety performed better on a multiple-choice exam when more of their
support came from outside of class than from peers within the same class [32]. Outside support came from more people, greater frequency, and was perceived as being more helpful by participants compared to peer support. This work differs as it examines support defined as supportive messages from peers or social media ties rather than self-reports of the frequency and helpfulness of peers and outside supports. In another domain, Coley and colleagues showed that messages written to smokers by other smokers increased their engagement on a smoking addicts website designed to help people quit smoking, when compared to messages written by experts [20]. Participants believed that the messages from other smokers were more social and authentic when compared to those of experts. The results from these two studies suggest that the domain likely matters when understanding how the content will effect perception, as people with similar experiences were less effective in Goldsmith’s work, but more effective in Coley’s.

2.2.3 OTHER FACTORS

Other factors demonstrated to affect perception of messages include medium and credibility. For example, Bioarsky and colleagues demonstrated that college students reported stronger intentions to follow positive health advice from an online health magazine story when compared to an online health blog with identical information [11]. Additionally, Kim showed that factors of credibility, such as professionalism and emotion, found on medical crowdfunding campaigns affect the likelihood that people will donate to a campaign [47]. My research questions focus on the authorship factor. Other factors should be considered in future work.

2.3 TEST ANXIETY

Test anxiety refers to the “set of phenomenological, physiological, and behavioral responses that accompany concern about possible negative consequences of failure on an exam
or similar evaluative situation” [74, 86]. Research in the domain focuses on understanding the
detrimental aspects anxiety causes before, during, and after exams. For example, Hollandsworth
and colleagues provided evidence that when compared to low test-anxious students, high test-
anxious students were at least one year behind national averages in mathematics, reading, and
basic skills performance and received lower report card grades [40]. Additionally, over a three-
year span, 20% of high test-anxious students dropped out of college compared to a 6% or lower
rate for low test-anxious students [77, 86]. As Sarason, a leader in test anxiety research stated,
“We live in a test-conscious, test-giving culture in which the lives of people are in part
determined by their test performance” [86]. Thus, reducing the consequences test anxiety has on
test performance is crucial.

2.3.1 Theories of Test Anxiety

Several models have been proposed to explain test anxiety. The most common model,
and the one I use in this dissertation, is the Transactional Process Model proposed by Spielberger
and Vagg. It decomposes test anxiety into two main factors, worry and emotionality [86]. The
worry factor focuses on the cognitive aspects of test anxiety such as pessimistic expectations,
absent-mindedness, self-criticism, and irrational outcomes. This aspect has been demonstrated to
negatively correlate with, $r^2 = .26$, with test performance [19]. Thus, the interventions I study and
the measure of test anxiety I use focus on the worry factor. The emotionality factor is comprised
of physiological responses such as heart rate, feeling of sickness, sweating, and tense muscles
[53, 86]. Alternative models decompose this factor further into three separate factors, tension,
test-irrelevant thinking, and bodily reactions, but methods of anxiety reduction addressing these
factors have demonstrated little ability to also affect performance [7, 71]. Other models of test
anxiety include the Skills-Deficit Model and the Cognitive-Attentional Model, but they too lack substantial experimental evidence of their ability to affect performance [86].

The belief that high test-anxious students are unprepared or lack either the skills or knowledge of the content being studied is a misconception. Although, some high test-anxious individuals lack appropriate study skills, improving this skill alone has not led to an increase in testing performance or to a reduction in anxiety [81]. Additionally, many high test-anxious students study on average longer than their low test-anxious counterparts and have demonstrated equal performance when examined in a less evaluative situation [86]. For many high test-anxious individuals, the irrelevant thinking anxiety causes diminishes their focus and attention increasing the time to retrieve information from memory. Examples include dwelling on the consequences of failure or calculating the number of points necessary to earn a “C” while completing the exam [86].

2.3.2 Measures of Test Anxiety

I use two measures of test anxiety in this dissertation, the Cognitive Test Anxiety (CTA) Scale and the State-Trait Anxiety Inventory (STAI). The CTA is a 27-item self-report questionnaire that focuses on behaviors before and during testing, including task-irrelevant thinking, making comparisons to others, and lapses in attention [19]. It ranges from 27 (lowest anxiety) to 108 (highest anxiety). It has an internal consistency of 0.86. I select this scale because it has a rich history of being applied to measure the worry or cognitive aspects of test anxiety that have demonstrated to be correlated with performance [19].

I use the STAI as a measure of trait anxiety and state anxiety. Trait anxiety is the personality characteristic anxiety of an individual, whereas state anxiety is anxiety of the moment. I use the state portion of the STAI to record pre- and post-anxiety, before and after the
interventions, as this measure changes based on current feelings. The state and trait aspects are measured separately with each twenty-item questionnaire ranging in score from 20 (lowest anxiety) to 80 (highest anxiety) [78]. The STAI has been validated in studies since 1980, with internal consistency coefficients ranging from .86 to .95 and test-retest reliability coefficients ranging from .65 to .75 [78].

Other measures of test anxiety include the Reactions to Tests, Test Anxiety Scale, and the Anticipatory Test Anxiety Scale [8, 69, 71]. These questionnaires focus on other factors of test anxiety including the emotionality factor or the decomposed components of the emotionality factor, tension, test-irrelevant thinking, and bodily reactions and were beyond the scope of this investigation. Physiological measures have also been studied, such as measures of electrodermal responses, respiration, and heart rate, but these approaches suffer from questionable construct validity, poor reliability, and are impractical in natural exam settings [86].

2.3.3 Anxiety and Open-Ended Questions

Prior work on test anxiety interventions focused on forced-choice questions. Though often used, the limitations of this format include the inability to effectively assess problem solving and creativity [6, 37]. In contrast, open-ended questions are considered to better measure these attributes but students perceive increased anxiety and uncertainty when solving them [76, 86]. For example, Zeidner showed that students found open-ended essay exams more difficult, complex, and anxiety provoking than multiple-choice exams [86]. Additionally, Schmidt and Crocker showed that low test-anxious students performed better on open-ended exams and high test-anxious students performed better on multiple-choice exams [72]. In this dissertation, I show how open-ended programming problems affect the anxiety of students and investigate the coping strategies students’ employ when solving them. My motivation for using open-ended
programming problems was due to my interest in computer science assessment, the ability to provide fast, consistent scoring for problems by using test cases, and the paucity of literature on the effectiveness of anxiety reduction techniques to help students solve open-ended problems.

### 2.3.4 Modality and Test Anxiety

In this dissertation, I study test anxiety in a computer-based setting as I examine how students perform on open-ended programming problems. Previous work has examined how student solutions differ between paper-based problems with flowcharts and diagrams and computer-based programming problems [34, 46]. Haghighi found that students with less programming experience reported higher levels of anxiety on the computer than on paper [34]. In other related work, Kim examined how modality affects the logical thinking of students in programming courses [46]. In two semester long courses, one that required computer programming and another that required only written logical thinking exercises, they found scores on the Group Assessment of Logical Thinking were unaffected, but no analysis was done on programming ability or anxiety [46]. I extend this literature by comparing paper-based exams where students write code with computer-based programming exams where students are equipped with programming tools. Additionally, I use a larger population of students than previous work and examine how preference changes across various years of study, courses, and prior exam experiences. In the next chapter, I present a study of the effects of modality on anxiety.
CHAPTER 3

EFFECTS OF MODALITY OF PROGRAMMING-CENTRIC EXAMS

Before beginning to investigate anxiety reduction methods I needed to examine how shifting programming-centric exams from paper to computer affected the anxiety of students and increase understanding of current coping strategies students used and the pervasiveness of test anxiety in engineering courses. This information would deepen the literature for how modality affects anxiety and demonstrate the need for novel reduction methods.

In this chapter, I present the results from a survey that had three goals: (1) to compare student perceptions of test anxiety on paper- and computer-based tests, (2) to investigate the coping strategies students use, and (3) to replicate previous work on modality preference, while deepening understanding of how modality preference changes as students progress through undergraduate curriculum. I chose to investigate coping strategies to understand how existing methods perform and the possibilities for improving them.

3.1 METHOD

The purpose of the survey was to compare student perceptions in speed, quality, anxiety, and preference of paper- and computer-based programming-centric exams. I also examined the coping strategies students used when completing programming-centric exams.
3.1.1 Survey Description

The survey consisted of seven Likert items and six open-ended questions as shown in Table 3.1. The first four rows show the Likert item questions. The Speed and Quality questions were asked for both paper and computer-based exams. Their purpose was to understand the student’s perception of the specific modality on measures of performance. They range from 1 (least favorable) to 7 (most favorable). The Anxiety question was also asked for both modalities and focused on the level of anxiety experienced by students. Responses to the question ranged from 1 (no anxiety) to 7 (extreme anxiety). The final Likert item, Preference asked students to indicate which modality they preferred and ranged from 1 (strongly prefer paper) to 7 (strongly prefer computer). The goal was to use this data to replicate previous research on student modality preference and examine how this changes as students’ progress through school.

The open-ended questions were asked to elicit qualitative data to explain student experiences and are shown in the last four rows of Table 3.1. The Process question focused on the student’s experiences and inner thoughts when dealing with anxiety to better understand the ratings provided to the Anxiety Likert item. The Cope question focused on the methods students currently apply to manage their anxiety on programming exams. The Benefit and Challenges questions were asked for both paper and computer-based exams and focused on students’ experience with the testing modalities.

3.1.2 Survey Distribution

The survey was distributed in two large undergraduate courses at a large mid-western institution. One course was a Computer Architecture course with 329 students. The course was offered in the computer science department and focused on logic design and machine-level programming. The other course was a Computer Systems and Programming course with 326 students. The
course was offered by the computer-engineering department and covered basic programming concepts in C, including functions, arrays, linked lists, and memory management. Both courses were comprised primarily of first semester sophomores and were part of each department’s core curriculum. The survey was distributed in the final month of the Spring 2015 semester.

<table>
<thead>
<tr>
<th>Question Key</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>What effect does taking a programming exam with [paper/computer tools] have on the quality of your solutions?</td>
</tr>
<tr>
<td>Speed</td>
<td>What effect does taking a programming exam with [paper/computer tools] have on your ability to finish quickly?</td>
</tr>
<tr>
<td>Anxiety</td>
<td>How much anxiety do you typically experience on programming exams given with [paper/computer tools]?</td>
</tr>
<tr>
<td>Preference</td>
<td>Please indicate your preference for how programming exams are given.</td>
</tr>
<tr>
<td>Cope</td>
<td>What are some of the ways you cope with anxiety during a programming exam?</td>
</tr>
<tr>
<td>Process</td>
<td>Think back to some of your previous programming exams. How did your anxiety affect your thought process, behavior, and/or experiences on the exam?</td>
</tr>
<tr>
<td>Challenge</td>
<td>What are the largest challenges you’ve experienced when taking a programming exam with [paper/computer tools]?</td>
</tr>
<tr>
<td>Benefit</td>
<td>What are the largest benefits you’ve experienced when taking a programming exam with [paper/computer tools]?</td>
</tr>
</tbody>
</table>

Table 3.1. Eight questions asked in the survey. The first four questions asked for ratings on a Likert scale, whereas the last four asked for open-ended responses. Note that [paper/computer tools] indicates the question was repeated for both modalities.

After I distributed the survey, I decided it would be beneficial to include additional open-ended questions to aid in understanding the responses to the Likert items. I modified the survey to include additional open-ended questions while some rating questions were removed to maintain a reasonable completion time. This variation was then disseminated to the computer science department’s undergraduate mailing list to get a broader perspective. The list contained 1,235 student emails. The data from students who participated in any prior surveys were
removed. The survey took approximately 15 minutes to complete and all participants were entered into a drawing to win two $25 gift cards. Responses were collected for one week.

3.1.3 PARTICIPANTS

In total 391 students responded yielding a response rate of 25%. Participants identified as 79% men and 21% women. Eighty-percent of participants declared a major or minor of computer science and 18% declared a major or minor of electrical engineering or computer engineering. Twenty-five percent of participants were in their first year, 45% in their second year, 19% in their third year, and 10% in their 4th year or higher. In addition, 23% of participants had only taken computer programming exams using paper, 8% of participants had only taken a computer programming exam on the computer, and 69% had taken exams on both paper and computer.

3.2 RESULTS

The frequency distribution of the perceived anxiety of participants reported for each modality is shown in Figure 3.1. In total 275 participants completed all the Likert items.

3.2.1 LIKERT RESPONSES

Figure 3.1 shows that 22% (n = 61) of participants perceive high anxiety (rating ≥ 6 on a 7-point scale) when writing code on paper-based exams and 23% (n = 64) perceive high anxiety when writing code on computer-based exams. In addition, a majority of participants report at least moderate levels of perceived anxiety (rating ≥ 4) for paper-based (69%; n = 189) and computer-based (64%; n = 176) exams. Forty-four percent (44%; n = 120) of participants rated higher levels of anxiety on paper-based exams when compared with computer-based exams with an average rating difference of 2.04, while 36% (n = 100) of participants rated higher levels of
anxiety on computer-based exams when compared with paper-based exams with an average difference of 2.15. Twenty percent (20%) of participants rated no difference in anxiety between modalities.

Figure 3.1: The frequency distribution of perceived anxiety reported by participants per modality. Darker bars represent paper and lighter bars indicate computer (N= 275). The x-axis ranges from 1 (no perceived anxiety) to 7 (high anxiety).

Figure 3.2 shows the frequency distribution of the modality preference for participants. Strong preference (rating ≥ 6) for computer-based testing (49%; n = 135) was observed. Additionally, a majority of participants had at least a moderate preference (rating ≥ 5) for computer-based testing (67%; n = 185). Twelve percent (n = 33) of participants had a strong preference (rating ≤ 2) for paper based exams and 21% (n = 58) had at least a moderate preference (rating ≤ 3) for paper based exams.

Means and standard deviations of four planned comparisons can be seen in Table 3.2. A Wilcoxon signed rank test showed that when exams were administered on a computer, students perceived their solutions to be of higher quality (µ = 5.09), and perceived faster development of
those solutions ($\mu = 4.94$) compared to when performing exams on paper ($\mu = 3.62$, $p < 0.001$, $\rho = 1.03$; $\mu = 3.40$, $p < 0.001$, $\rho = 0.98$; respectively).

Another Wilcoxon signed rank test revealed participants reported no difference in perceived anxiety for paper ($\mu = 4.26$) and computer-based exams ($\mu = 4.15$, $p = 0.39$). A one-sample Wilcoxon signed rank test was used to compare the student modality preferences against

<table>
<thead>
<tr>
<th>Question Key</th>
<th>Paper</th>
<th>Computer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>3.62 (1.44)</td>
<td>5.09** (1.35)</td>
</tr>
<tr>
<td>Speed</td>
<td>3.40 (1.58)</td>
<td>4.94** (1.55)</td>
</tr>
<tr>
<td>Anxiety</td>
<td>4.26 (1.51)</td>
<td>4.15 (1.67)</td>
</tr>
<tr>
<td>Preference</td>
<td>58</td>
<td>185**</td>
</tr>
</tbody>
</table>

Table 3.2: The means and standard deviations for survey responses Quality, Speed, and Anxiety. The fourth row shows the counts for the survey responses to the Preference question. ** means $p < 0.001$
no preference (rating = 4). The test showed a significant preference for computer-based testing
(\(\mu = 5.04, \sigma = 1.8, p < 0.001, d = 0.82\)).

<table>
<thead>
<tr>
<th>Modality</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>4.27 (1.52)</td>
<td>4.25 (1.51)</td>
</tr>
<tr>
<td>Computer</td>
<td>4.78* (1.51)</td>
<td>3.99* (1.67)</td>
</tr>
</tbody>
</table>

Table 3.3: The means and standard deviations for the survey response Anxiety for women (N = 55) and men (N = 220). * means \(p < 0.05\). The significant differences are between the paper and computer modality (within gender).

As text anxiety has been found to disproportionately affect women, gender differences were examined [64]. Table 3.3 shows the means and standard deviations for perceived anxiety reported by gender. Two Wilcoxon signed rank tests revealed women reported higher levels of perceived anxiety for computer-based exams (\(\mu = 4.78\)) than paper-based exams (\(\mu = 4.27; p = 0.05\)). Men reported the opposite pattern: they reported lower perceived anxiety for exams taken on a computer (\(\mu = 3.99\)) than on paper (\(\mu = 4.25; p = 0.05\)). No gender differences were detected for perceptions of solution quality, speed, or modality preferences. A Kruskal-Wallis test showed that no difference existed between modality experiences (\(\chi^2 = 2.09, p = 0.35\)). A Jonckheere-Terpstra Test showed that there was a significant trend in preference for paper-based testing as year in school increased (1st year, \(\mu = 5.57\); 4th+ year, \(\mu = 5.06; p = 0.0386\)). This could indicate that as the complexity of course content increases; students perceive fewer benefits from using tools to write code on exams.

3.2.2 Open-ended Responses

The open-ended responses were coded by segmenting them into idea units. An initial pass of the data assigned thematic codes to each unit. Subsequent passes were then performed to aggregate the existing codes and form more abstract categories. This continued until the themes
were perceived to be reasonably exclusive. When reporting each theme, the number of
participants who shared that response is provided.

The responses to the “Cope” question yielded three common themes. The first theme,
“Relaxation techniques,” included responses centered on breathing or taking a break (n = 31 out
of 94). For example, P58 stated they “take some time to calm and simply zone out and take a
mental break for a bit.” The second theme was participants who experienced anxiety, but had no
strategy for coping (n = 25). For example, P64 stated, “I don’t [have a strategy]. Haha.
Programming exams are super stressful.” The third theme was “Writing” which included
behavior such as drawing pictures, writing checklist, or writing pseudocode (n = 12). P28, for
example, wrote, “[I write] loads of comments to help me flesh out my thoughts.”

The responses to the “Process” question yielded three themes. The first theme,
“Difficulty focusing” consisted of behaviors, such as blanking out or being easily distracted (n = 27 out of 78). P80, for example, stated that it is “really hard to think clearly and logically”. The
second theme, “Increased mistakes” focused on small mistakes that participants perceive they
make that they wouldn’t if not for feeling anxious (n = 17). For example, P96 stated, “my
anxiety made it harder...causing me to make mistakes I normally wouldn’t.” The third theme,
“Increased worry” focused on behavior such as feelings of being unconfident in easy solutions,
continuously checking answers, and worrying about forgetting simple things (n = 10). For
example, P85 stated “I have a tendency to second-guess things I would otherwise be sure of.”

The responses to the “Challenge” question when asked regarding paper exams, yielded
four major themes. The first theme, “Organization” focused on responses involving making
edits, space constraints, and legibility (n = 44 out of 116). For example, P60 stated, “Basic
formatting, cleanliness, and erasing mistakes,” were challenges for paper exams. The second
theme, “Remembering syntax” contained challenges such as remembering function names, forgetting semicolons, and other small errors (n = 40). For example, P52 stated, “remembering the syntax or function names,” were challenges. The third theme is “Confidence” which contained responses about being unable to compile their solutions and lacking confidence that portions of their code worked as expected (n = 28). For example, P3 stated they “have a hard time being confident in my programming answers.” The fourth theme is “Pace.” This contained responses around running out of time during the exam due to slow writing speed, hand cramps, or spending too much time debugging (n = 19). For example, P23 stated that “the sheer amount of time it takes to write stuff out,” was a challenge.

When the “Challenge” question was asked regarding computer-based exams, two themes were discovered. The first theme, “Anxiety” contained responses from students feeling increased stress, panicking, or feeling scared due to the testing environment, debugging, or time pressure (n = 24 out of 66). For example, P30 stated, “when I find a bug in my code and time is running out, I tend to panic.” The second theme, “Partial credit” focused on students stating a decrease in their exam score versus when on paper, due to less partial credit (n = 12). For example, P11 stated, “it’s usually all or nothing. Not a lot of partial credit if you make a mistake.”

The “Benefit” question was also asked about both modalities. When discussing paper testing, this question yielded two themes. The first theme focused on cognition. This theme contained responses about how the modality helped participants think about the problem better or helped them learn the process better when studying (n = 28 out of 116). For example, P116 stated that paper testing, “makes you think critically about the problem without relying on a compiler.” The second theme “Partial credit” focused on gaining points even if the program doesn’t entirely work (n = 27). For example, P58 stated, “graders tend to be more lax with partial
credit,” which generally increased the student’s score. In addition, 28 participants reported perceiving no benefit to writing code on a paper-based exam.

When discussing computer-based testing, the “Benefit” question yielded 3 themes. The first theme, “Feedback” consisted of responses around being able to compile solutions, use IDE tools, and increased confidence (n = 47 out of 68). For example, P12 stated, “I can be more confident in my answer before moving onto the next problem.” This was due to being able to compile and test the solution. The second theme, “Organization” focused on the ability to edit and organize code clearly (n = 16). For example, P31 stated, “The ability to rearrange lines of code easily,” was a benefit for programming on the computer. The third theme, “Familiarity” focused on the environment being more realistic and familiar (n = 10). For example, P8 stated the environment “more closely resembled an actual programming environment.”

3.3 DISCUSSION

The goals of this survey were to: (1) compare student perceptions of test anxiety on paper- and computer-based tests, (2) investigate the coping strategies students use, and (3) replicate previous work on modality preference, while deepening understanding of how modality preference changes as students progress through school.

3.3.1 IMPLICATIONS

The results showed that a majority of students reported at least moderate anxiety (rating ≥ 4) during both paper (69%) and computer (64%) exams. Additionally, a notable percentage of students reported high levels of perceived anxiety (rating ≥ 6 on a 7-point scale) when taking exams on paper (22%) and computer (23%). These findings support prior work by Asghari and Kavakci on the prevalence of test anxiety in other fields of study [2, 45]. The aggregate findings
indicate that the modality of programming-centric exams has little affect on student perceptions of test anxiety. With 36% of students perceiving an increase in anxiety when taking programming exams on the computer instead of paper and 44% displaying the opposite effect, an increase in anxiety when solving programming questions on paper when compared to computer, instructors should consider how choice of modality affects over one-third of students. A choice of testing modality for students might be one approach to limiting the increased anxiety students experience to obtain an accurate assessment of student knowledge. The benefits described in the open-ended questions for computer-based programming-centric exams, such as increased confidence and familiarity, are aspects that relate to test anxiety reduction [86]. However, experiencing anxiety was still the largest theme reported when asked about the challenges students experience during computer-based exams. This provides support for the inclusion of anxiety reduction methods into the testing process.

Examining the impact modality had on student performance showed that participants perceived an increase in their solution quality and speed of solution development during computer-based exams. However, the data showed while men report a decrease in anxiety on computer-based exams when compared with paper-based exams, women report the opposite effect, their anxiety increases on computer-based exams when compared with paper-based exams. Women are minorities in courses with computer programming and prior work shows that women experience disproportionately higher anxiety relative to men [28, 55, 67]. Future studies are needed to examine how the use of an examination method that increases their anxiety when compared to traditional methods affects the performance and retention of women.

The results demonstrated that 67% of students at least moderately preferred (rating ≥ 5) computer-based to paper-based testing, consistent with prior work showing that about 75% of
students preferred computer-based testing for a computer science exam. However, I also found that as student year in school increased they preferred paper-based exams. This result contradicted some of Haghighi’s work where they found that students preferred computer-based testing as their programming experience increased [34]. This difference might exist because in Haghighi’s work participants were all in the same introductory level course where programming experience was measured as a binary variable, either students had experience or did not, whereas I measured programming experience as a year of study in an undergraduate program.

Lastly, the results showed that the coping strategies students used included relaxation techniques, drawing, and writing. Importantly, 22% of students stated that they experienced anxiety, but did not have a coping strategy. Relevant theory divides coping strategies into problem-focused methods and emotion-focused methods [10, 30]. When people employ problem-focused coping strategies they perform “behaviors designed to reduce or eliminate the problem in question” [10]. An example is writing an action plan or pseudocode for a problem. When people employ emotion-focused strategies they exhibit “behaviors designed to reduce negative emotional reactions” [10]. Some examples collected from participants were wishful thinking and tension-reduction. Previous work has shown that problem-focused strategies are more effective than emotion-focused strategies [10], yet emotion-focused strategies are employed more often by students in testing situations [52]. In this study, relaxation techniques, one form of an emotion-focused strategy, were found to be the most prevalent with 27% of students adopting this strategy. Encouraging more problem-focused strategies, such as writing pseudocode or developing a solution plan, may be more effective. I found only 10% of students used these approaches. In addition, students who have not developed coping strategies, such as the 22% in this study, could benefit from learning and applying more effective techniques.
Additionally, the test anxiety literature explores coping strategies used during the four phases of the testing process. Introducing interventions at the beginning of the exam could be an approach to help each student have an effective method of coping with their anxiety. For example, recently Ramirez showed that an expressive writing exercise at the start of an exam helped high test-anxious students increase exam scores on a multiple-choice biology exam [65]. The value of this approach seems apparent, but more research is needed to understand how these coping strategies work on computer-based programming exams with open-ended problems and to measure the anxiety difference student’s report when using confrontation stage anxiety reduction methods.

3.3.2 Limitations

This study had several limitations. First, perceived anxiety was measured through the use of self-reports on a custom survey. It was not realistic to validate these subjective ratings against objective measures (e.g. physiological measures). The survey also measured anxiety holistically, and did not tease apart its multiple dimensions as found in longer instruments targeting anxiety, such as the Reactions to Tests [71]. Second, the participant selection was limited to a single university. A third limitation is that the sample consisted of mostly computer science and computer engineering students, which may not be representative of the entire population that takes programming-centric exams. A final limitation is that we only one-coder was used in labeling the data, however the level of granularity was high enough to capture the broad categories of responses.
3.3.3 Future Work

In my future work, I want to generalize these findings by conducting a similar survey at additional institutions and including populations of students who learn to program in disciplines outside of computer science (and STEM). Another future direction is to deepen and extend these findings by conducting interviews with students and collecting physiological measures of anxiety to further support the survey data. A final direction would be to utilize the infrastructure of computer-based programming exams to study various coping strategies for students experiencing anxiety. For example, the expressive writing intervention demonstrated by Ramirez and his colleagues could be embedded in the testing process [65]. This would deepen literature on expressive writing and demonstrate its affects on test anxiety for students taking open-ended programming exams. Another possibility would be to examine how social support could aid test-anxious students. Sarason demonstrated that test-anxious students who overheard a supportive message scored higher than test-anxious students who did not [70]. An approach that uses the social network of students to obtain supportive messages could further demonstrate the use of social support as a test anxiety intervention.
CHAPTER 4

COMPARING ANXIETY INTERVENTIONS FOR OPEN-ENDED PROGRAMMING PROBLEMS

Popular methods such as systematic desensitization and cognitive behavior therapy have demonstrated to be effective in reducing test anxiety for students. However, these methods are expensive, time consuming, and are only applied in the most severe cases of test anxiety. A more accessible method of test anxiety reduction is expressive writing. Ramirez and colleagues showed that a ten-minute writing task before a forced-choice question exam could increase the scores of high test-anxious students by half of a letter grade [65]. These results were promising for quick anxiety reduction strategies and extending these findings to open-ended exams would allow for a large impact across assessment formats. Additionally, these researchers showed that anxiety reduction strategies could be effective when provided immediately before the exam, opening up the possibilities for other methods before the exam.

The novel method I explore is providing social support using supportive messages. Supportive messages have demonstrated to effectively influence health behavior changes, effort when exercising, and video game experiences [1, 29, 44, 79]. Exploring if this method can also be applied to test anxiety reduction and how effective it is can aid in addressing the problem of test anxiety.

In this chapter, I present an experimental study that had three goals: (1) to compare how social support, expressive writing, and reading task-related information affect the anxiety experienced by students during an open-ended exam, (2) to demonstrate how the level of test
anxiety relates to the correctness of programming solutions on an exam, and (3) to survey student perceptions about completing an expressive writing task or soliciting social support from social media.

4.1 METHOD

A single factor between-subjects lab experiment was performed to investigate the differences in these anxiety interventions. The factor was Anxiety Intervention (social support vs. expressive writing vs. control) and participants were randomly split into groups representing each factor level. Participants were recruited from the computer science department at a large mid-western university. The instructor of a Spring 2016 Data Structures course sent an email to the course of 600 students offering an extra credit incentive for participation. Additionally, an announcement was sent to a department mailing list comprised of 1,235 email addresses. Students who were enrolled in the course received 1% point extra credit for participating and students not in the course received $10. Additionally, all participants were entered into a multi-winner lottery for $100. In total, 88 participants completed all parts of the experiment.

4.1.1 PARTICIPANTS

Seven-eight percent (78%) of participants identified as men, 20% identifies as women, and 2% did not respond. Most participants (94%) were enrolled in the Spring 2016 Data Structures course. Participants were mostly engineering students majoring in computer science (52%), computer engineering (16%), and electrical engineering (7%). Half (51%) of participants were in their first year of undergraduate studies, (30%) were in their second year, (14%) were in their third year, and (5%) were in their fourth year. About one third (31%) of participants reported previously using Facebook to request encouragement from their social network.
4.1.2 Tasks

Two programming problems were chosen for this study and both were to be completed using C++ the language used in the data structures course. The first problem required traversing a binary tree. Participants were asked to write a function that returned the number of nodes in a binary tree that have exactly one child. This problem was selected because it used concepts of recursion and data structures that participants were expected to be familiar. The second problem required manipulation of a singly linked list. It was selected because it was similar to a question from a prior midterm in the course. It required participants to write a function that removed nodes from a singly linked list if the node’s string data element was longer than a given threshold. The function would then return the number of nodes removed and the resulting updated linked list. Both problems had many viable solutions in terms of memory efficiency, complexity, and choice of language constructs. The solutions showed that no two students produced identical solutions to both problems. Instructions for the problems can be seen in Figures 4.1.

Participants were provided with a source code text editor (Emacs or Vim depending on the student’s preference). A source code text editor was provided because the students were familiar with the editors as they used them in their coursework and on exams that required them to write code. Additionally, students were able to compile and run their code, both of which were allowed in the course exams I intended to simulate. It was estimated that students were expected to complete each problem within 20 minutes, so participants were provided with 40 minutes complete the two problems. A pilot study revealed that participants believed the problems were appropriate for their level of knowledge and the amount of time provided was adequate.
1. (50 points) You are given the TreeNode class in file question1.cpp. You want to write a function countSingleParents that has one parameter. The parameter is of type pointer-to-TreeNode, and points to a binary tree (which could be empty). You want to return an integer that is the number of nodes in the parameter binary tree that have exactly one child node.

You can compile your code via the command line using g++ question1.cpp and run it using ./a.out.

2. (50 points) You are given the ListNode class in file question2.cpp. You want to write a function removeLongWords that has two parameters. The first parameter is of type pointer-to-ListNode, and points to a singly linked list made up of objects of type ListNode. If the list is empty then head will point to NULL. The second parameter is an integer, threshold. You want to remove each ListNode in the linked list that have a word longer in length than threshold. You also want to return the number of nodes removed.

Whatever linked list this results in, the head parameter should be pointing to the first node of the list when you are done. You can not reassign the word variable within a ListNode.

You can compile your code via command line using g++ question2.cpp and run it using ./a.out

Figure 4.1. Instructions for the two programming problems.

4.1.3 Anxiety Interventions

The study compared a novel intervention of using social media to provide social support before an exam, to the more studied intervention of expressive writing and the more practiced method of reading task-relevant information. The interventions were administered prior to participants performing the programming tasks. In the expressive writing condition, participants were given the prompt shown in Figure 4.2 and wrote their response into an online form, similar to the procedure of [61, 65]. Participants in the social support condition adapted a template message and posted it to their Facebook Timeline the day before the experiment (see Figure 4.3). They were informed that just prior to the experiment, they could view the likes, comments, and private messages associated with their post. Participants were instructed to refrain from viewing the responses until they arrived for the study. I chose to implement social support using a social media platform because the approach is scalable, accessible, and fast; features which I believe
would increase the likelihood that student would use this approach in practice and receive timely responses. I chose Facebook since its network is based on social relationships. In the control condition, participants read general information regarding computer programming data structures before completing the programming tasks. The control condition was intended to represent common student behavior of reviewing course material immediately before an exam.

Table 4.2. Prompt for the expressive writing condition.

4.1.4 Measures

The Cognitive Test Anxiety scale (CTA) and the State Trait Anxiety Inventory (STAI) were used to measure participant cognitive test, state, and trait anxieties [19, 78]. The CTA is a 27-item questionnaire that focuses on behaviors before and during testing, including task-irrelevant thinking, making comparisons to others, and lapses in attention. It ranges from 27 (lowest anxiety) to 108 (highest anxiety). Previous studies classify a sample of participants as low or high test-anxious based on scoring in higher or lower percentiles [9, 32]. The STAI measures state (of the moment) and trait (of the person) anxiety with two twenty-item questionnaires. Each questionnaire ranges in score from 20 (lowest anxiety) to 80 (highest anxiety). Due to experimenter oversight, the state portion of the STAI was measured using
nineteen of the twenty items, adjusting the range from 19 to 76. The effects of this omission on
the data were believed to be inconsequential.

A post-task survey was administered to participants. It consisted of the following two
five-point Likert item questions: “[Intervention] helped reduce my stress or anxiety” and “I
would [intervention] before a course exam,” where [intervention] reflected the condition. The
questions ranged from 1 (Strongly Disagree) to 5 (Strongly Agree) and participants were asked
to explain their selection in an open-ended text prompt. The goal was to gauge student
perceptions of the assigned anxiety intervention. The open-ended responses were partitioned into
idea units. Thematic codes were then assigned to each unit on an initial pass, and subsequent
passes were made to group similar themes into more abstract categories until they were
reasonably exclusive. The programming problems were scored using 6 input test cases for the
binary tree problem and 10 input test cases for the linked list problem. Though the number of test
cases differed for the two problems, both problems were weighted equally. The total score for
the problems ranged from 0-100. Evaluations were performed blind to condition.

4.1.5 Procedure

After obtaining informed consent, participants were asked to complete an online form
containing questions asking how many years of programming experience they had and what
gender they identified with. The form also asked them to provide a self-rating of their C++
experience. In addition, participants completed the Cognitive Test Anxiety instrument and the
trait portion of the State-Trait Anxiety Inventory (STAI). Participants were also asked about
their willingness to post a message to Facebook as part of the study and if they had ever used
Facebook to solicit social support. Finally, participants completed a five-question multiple
choice pre-test. The pre-test focused on basic data structures, runtime complexity, and C++
syntax and can be seen in Appendix A. It was used to ensure participants had a basic understanding of programming.

Participants were then randomly assigned to conditions. Participants assigned to the social support condition were asked to adapt a template message and post it to their Facebook Timeline (Figure 4.3). They were informed that they could modify the text to fit their style, but any modification should still convey the message of when the programming task occurs, that they will have the opportunity to read the responses, and that supportive comments would be valued.

```
Hi friends, I need your encouragement. I will be competing in a computer programming challenge on Monday. I will have the opportunity to view comments and likes you put on this post during the challenge. I will also be able to see private messages. I won’t be able to respond to any of your messages at that time, but I will be able to read them. Any supportive comments would be great to see.
```

**Figure 4.3. The template text participants in the social support condition adapted and posted to Facebook.**

Upon arriving at the study location, the experiment followed the process shown in Figure 4.4. An experimenter instructed participants that they would have forty minutes to complete two programming problems and described the remuneration. The experimenter then presented a scenario designed to induce increased anxiety. Participants were informed that they would receive an additional $100 for earning a perfect score on the programming problems and $10 if each member of their assigned group, determined by arrival order, scored at least a 75% score on the problems. This method of using a monetary incentive along with the feelings of wanting to perform well relative to peers, follows similar work on methods used to increase anxiety in a situation [65]. A pilot study also revealed that participants reported feeling increased anxiety if they could see the members of their group working and if they thought that they should be able
to complete the problems. Thus, groups were assigned in view of participants and participants were told that the programming problems were based on their expertise as measured by the pre-test problems.

Figure 4.4. A summary of the experimental procedure. Participants were briefed and completed the state anxiety form. Participants then performed the assigned intervention and completed the state anxiety form again. The coding tasks were then performed, followed by a survey.

After hearing this information, participants logged on to a lab computer and worked in view of other participants. This design was employed to mimic authentic exam situations where students can see each other when working. In the lab, students first completed the state portion of the STAI to obtain a pre-condition state anxiety measurement. Participants then performed a seven-minute intervention based on the assigned condition. Control group participants read relevant material on data structures and answered three questions about the text (Figure 4.5). Participants in the expressive writing condition were presented with the interface in Figure 4.6 and typed their response. Participants in the social support condition viewed the comments, likes, and private messages they received from their prior post. They were asked to report the number of responses received and which response made them feel most supported. An example post with responses is shown in Figure 4.7. As a manipulation check, participants reported their perception of how supportive the responses to the post were.
After completing the intervention, all participants completed the state portion of the STAI again to obtain a post-intervention measurement. Participants were then presented with two programming tasks and had 40 minutes to complete them. Afterward, participants completed a post-task survey that focused on their perceptions of how the control, expressive writing, or social support activity affected their anxiety and if they would perform a similar activity before a course exam.
4.2 RESULTS

ANOVA\'s confirmed that participants in each condition did not differ for their initial state anxiety ($F(2, 82) = 1.69, p = 0.32$), C++ experience ($F(2, 82) = 0.79, p = 0.46$), cognitive test anxiety ($F(2, 82) = 1.69, p = 0.19$), trait anxiety ($F(2, 82) = 1.90, p = 0.16$), and pre-test scores ($F(2, 82) = 0.13, p = 0.88$). Table 4.1 shows the means for these factors. Additionally, results showed that the CTA, state, and trait anxiety metrics had moderately positive correlations, as expected. Table 4.2 shows the correlations for these factors.

A Wilcoxon signed rank test revealed that participants in the social support condition found the responses they received to be supportive, ($\mu=4.62, \sigma=0.82, p < .001, d=2.80$),
confirming the manipulation and corroborating prior work [13]. The average number of likes, comments, and private messages per post were 41.8, 12.5, and 1.38, respectively.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Expressive Writing</th>
<th>Social Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial State Anxiety</td>
<td>36.34</td>
<td>40.66</td>
<td>37.86</td>
</tr>
<tr>
<td>C++ Experience</td>
<td>2.86</td>
<td>2.93</td>
<td>3.10</td>
</tr>
<tr>
<td>CTA Score</td>
<td>63.45</td>
<td>71.4</td>
<td>66.66</td>
</tr>
<tr>
<td>Trait Anxiety</td>
<td>44.31</td>
<td>48.1</td>
<td>42.97</td>
</tr>
<tr>
<td>Pre-test Score</td>
<td>3.56</td>
<td>3.43</td>
<td>3.52</td>
</tr>
</tbody>
</table>

Table 4.1. The mean values for the initial state anxiety, C++ experience, CTA score, trait anxiety, and pre-test scores for participants in each condition. All differences between means were found to not be statistically significant.

<table>
<thead>
<tr>
<th></th>
<th>CTA</th>
<th>Trait</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTA</td>
<td>1</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Trait Anxiety</td>
<td>0.64**</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Initial State Anxiety</td>
<td>0.73**</td>
<td>0.60**</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4.2. The correlations between the anxiety metrics. The CTA, trait anxiety, and initial state anxiety had moderate positive correlations. ** Indicates significance at the p < .001 level.

Figure 4.8, Figure 4.9, and Figure 4.10 show the state anxiety of participants before and after the assigned anxiety intervention. Figure 4.8 shows that participants in the control group were largely unaffected by the task relevant reading activity. Figure 4.9 and Figure 4.10 show that participants in the social support and expressive writing conditions were affected differently and I discuss these differences below.
Figure 4.8. State anxieties before (X-axis) and after (Y-axis) the control condition. The dotted line indicates perfect correlation and the solid line is the regression line for the data ($R^2=0.8$).

Figure 4.9. State anxieties before (X-axis) and after (Y-axis) the social support condition. The dotted line indicates perfect correlation and the solid line is the regression line for the data ($R^2=0.61$).

Figure 4.10. State anxieties before (X-axis) and after (Y-axis) the expressive writing condition. The dotted line indicates perfect correlation and the solid line is the regression line for the data ($R^2=0.1$).
4.2.1 Effects on Anxiety

Table 4.3 shows the means for the initial state anxiety and the post state anxiety for each condition. Differences between the two state anxiety measurements for each participant were computed. A one-way ANCOVA with the difference scores as the dependent variable and anxiety intervention as the factor was then conducted. The Cognitive Test Anxiety score was included as a covariate. Results showed a main effect ($F(2,82)=21.59, p < 0.001$) and post-hoc comparisons showed that the social support condition ($\mu=5.67$) had a larger decrease in anxiety than the control condition ($\mu=1.28$). Also, the control condition had a larger decrease in anxiety than the expressive writing condition ($\mu=-5.3$).

<table>
<thead>
<tr>
<th></th>
<th>Low CTA</th>
<th>High CTA</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Count</td>
</tr>
<tr>
<td>Control</td>
<td>32 (7.9)</td>
<td>29.2 (7.1)</td>
<td>12</td>
</tr>
<tr>
<td>Writing</td>
<td>28.7 (7.2)</td>
<td>47 (2.9)</td>
<td>11</td>
</tr>
<tr>
<td>Social</td>
<td>28.7 (7.0)</td>
<td>26.2 (6.7)</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 4.3. The pre / post state anxiety scores grouped by condition and CTA cluster. For each CTA cluster, the initial state anxiety (SD) is in the Pre column, the post state anxiety (SD) is in the Post column, and the number of participants is in the Count column.

A correlational analysis between the social media interactions (likes, comments, and private messages) and anxiety difference scores were performed. The more substantive responses (comments and private messages), which will be collectively referred to as messages, were compared to less substantive “likes”. A moderately positive relationship between the number of messages received and anxiety difference scores ($r=0.55, p=0.002, n=29$) was found, whereas the relationship between likes and anxiety difference scores was not significant ($r=0.32, p=0.09, n=29$).
Based on this main result and prior work, participants were classified as “Low anxiety” if they scored in the bottom 40th percentile on the CTA and as “High anxiety” if they scored in the upper 40th percentile [19]. Table 4.3 shows the mean state anxiety before and after the intervention for each classification.

An ANOVA with anxiety difference as the dependent variable and the CTA cluster and intervention as factors was performed. For the control condition, no difference was found between the two CTA clusters on the difference scores, $F(1,18)=0.79, p=0.39$. For the social support condition, the analysis showed that the “High Anxiety” participants experienced a larger decrease in anxiety ($\mu=9.8$) than the “Low Anxiety” participants ($\mu=2.5; F(1, 21)=5.76, p=0.03$). For the expressive writing condition, the “Low Anxiety” participants experienced a larger increase in anxiety ($\mu=-18.3$) than the “High Anxiety” participants ($\mu=3.3; F(1,24)=30.13, p < 0.001$). These results indicate that social support decreased anxiety, especially for the “High Anxiety” participants, whereas expressive writing increased the anxiety for “Low Anxiety” participants.

4.2.2 Effects on Performance

To examine how the anxiety intervention affected the correctness of the programming solutions, a one-way ANCOVA using Cognitive Test Anxiety score as a covariate, was conducted. Results showed an interaction between factors ($F(2,82) = 3.24, p = 0.04$). To examine it, an ANOVA, with correctness of solutions as the dependent variable and the CTA classification and anxiety intervention as factors, was performed. The results can be seen in Table 4.4.
Table 4.4. Means and (standard deviations) of the programming task scores grouped by condition and CTA cluster.

<table>
<thead>
<tr>
<th></th>
<th>Low CTA</th>
<th>High CTA</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>77.4 (29.8)</td>
<td>38.3 (24.9)</td>
<td>63.2 (30.9)</td>
</tr>
<tr>
<td>Writing</td>
<td>74.1 (25.6)</td>
<td>54.4 (28.2)</td>
<td>61.2 (31.3)</td>
</tr>
<tr>
<td>Social</td>
<td>62.7 (20.5)</td>
<td>67.4 (38.1)</td>
<td>67.6 (31.8)</td>
</tr>
</tbody>
</table>

For the social support condition, the “High Anxiety” (µ=67.4, σ=38.1) and “Low Anxiety” (µ=62.7, σ=20.5) participants showed no difference in the correctness of programming solutions (F(1,21) = 0.13, p = 0.724, d = 0.15). Additionally, a correlational analysis between the social media interactions and performance scores revealed no significant relationships. In the expressive writing condition, the analysis showed a large noticeable difference between the means of the “High Anxiety” (µ=54.4, σ=28.2) and “Low Anxiety” (µ=74.1, σ=25.6) participants, but the analysis showed only a marginal effect (F(1,24) = 3.32, p = 0.08, d = 0.70).

Consistent with prior work, in the control condition the “High Anxiety” participants scored significantly worse on the programming solutions (µ=38.3, σ=24.9) than the “Low Anxiety” participants (µ=77.4, σ=29.8; F(1,18)=9.35, p=0.007, d=1.16). Together, these results indicate that both social support and expressive writing allowed the high test anxiety participants to perform as well as the low anxiety participants.

### 4.2.3 Participant Perceptions

Participants in the social support condition were asked to explain which post made them feel most supported. The analysis found that the authors of the posts participants identified included close friends, family members, people they admired, and friends who the participant had not recently communicated with. For example, one participant stated, “One of my friends privately reached out to me to express her support. She is one of my smartest friends, and it felt comforting to have her support going into this challenge. (P62)” The results showed various
reasons for why the particular post made them feel supported, including it increased their confidence, put them at ease, made them laugh, or was unexpected. Some participants stated the effort others made by writing personal responses, finding supportive quotes from noteworthy people, or praying on behalf of the participant encouraged them. For example, one participant stated that their family member said, “You do your best work with the word ‘challenge’ in it. Prayers are starting as of now.” This participant said it was “encouraging to know that she was taking time out of her day to pray for me. (P71)”

To evaluate responses about how participants perceived the effects of the assigned intervention on their anxiety, Wilcoxon signed rank tests were conducted on responses to the question “[Intervention] helped reduce my stress or anxiety.” [Intervention] was replaced by the assigned condition. A Bonferroni adjustment was used on the significance threshold to be $p = 0.05/3 = 0.016$. The analysis showed that the control and writing conditions had moderate effect sizes on perceived anxiety compared to a Neutral response, but were not significant: ($\mu=3.45$, $\sigma=1.05$, $p=0.04$, $d=0.60$) and ($\mu=3.3$, $\sigma=0.92$, $p=0.09$, $d=0.46$) respectively. In the social support condition, participants reported the responses significantly decreased their perceived anxiety ($\mu=3.59$, $\sigma=0.63$, $p < 0.001$, $d=1.33$) when compared to a Neutral response. These results are consistent with the quantitative findings using the STAI measure.

From the open-ended responses explaining their rating, the main theme from the social support condition was “Emotionally Beneficial” (n = 31). The “n =” indicates how many occurrences of this theme were in the data based on the previously mentioned coding scheme. This theme focused on liking the encouragement received and its ability to help them relax and increase their confidence. One participant stated, “They restored my self-confidence,” (P77) when referring to the Facebook friends that left responses on their post.
In the expressive writing condition, the two largest themes were “Emotionally Beneficial” and “Not Useful.” The “Emotionally Beneficial” theme (n = 13) stated that the activity helped them feel better, and reduced their anxiety. For example, one participant stated, “After I write down the feeling I can calm down easier. (P45)” The other theme was “Not useful” (n = 8). Participants in this theme stated that the activity did not affect them. For example, one participant stated, “I don’t think it really helped that much with reducing any anxiety that I had. (P34)” Participants also mentioned three minor themes: “Self-reflection,” “Increased Focus,” and “Increased Anxiety.” Participants who stated that expressive writing helped with their self-reflection focused on how writing helped them get to the root of why they were experiencing anxiety (n = 3). In the “Increased Focus” group (n = 5), participants stated that it helped them to ignore other distractions once the programming tasks began. Finally, the “Increased Anxiety” participants stated that expressive writing made them feel more panicked (n = 4). For example P60 stated that expressive writing “…made me panic more. Since I was detailing how I was feeling, my body started paying attention to every way my body was reacting and it amplified my nervousness.”

In the control condition, three themes emerged: “Mentally Beneficial,” “Emotionally Beneficial,” and “Not Useful.” The “Mentally Beneficial” theme (n=11) contained responses that stated the reading helped refresh their memory or gave them an idea of what to expect. For example, one participant stated that it “helped me gather my thoughts” and was a “valuable refresher that helped me to remember the general ideas which made it easier to think of the finer details later on. (P15)” The “Emotionally Beneficial” theme (n=10) contained responses about increases in confidence and decreases in anxiety or stress. For example, one participant stated that the reading “helped boost my confidence, (P16)” and another stated that it “put me at ease.
Participants in the “Not Useful” theme (n=11) made statements such as “It did nothing for me (P29)” or “I knew nearly everything that was written. (P2)”

For the second question, “I would like to use [intervention] before a course exam,” a one-sample Wilcoxon signed rank test was conducted on the responses, and the significance threshold was adjusted again using a Bonferroni adjustment ($p = 0.05/3 = 0.016$). The results showed that participants in the writing condition showed no difference from a Neutral response in how they answered the question ($\mu = 2.77, \sigma = 1.14, p = 0.25, d = 0.29$). Participants in the control condition strongly favored referring to notes before an exam over a Neutral option ($\mu = 4.0, \sigma = 0.86, p < 0.001, d = 1.67$). Additionally, participants in the social support condition reported they would not elicit support of their Facebook friends before a course exam ($\mu = 2.34, \sigma = 1.14, p = 0.005, d = 0.81$).

The open-ended responses explaining the rating revealed two themes in the control condition: “Reinforcement” and “Information Dependent.” For “Reinforcement” (n = 15), participants stated that they would prefer to read course notes before an exam because it boosted their confidence, provided a refresher, and calmed them. One participant stated, “I would like to read before exam. Because it helps me to review the topic in class and gives me more confidence. (P7)” For “Information Dependent” (n = 5), participants stated that they would like to review course notes before an exam only if they did not know the material. One participant stated, “If I wasn't well versed in a topic, it would be extremely helpful to read general information before taking an exam. (P8)”

In the writing condition, there were two major themes: “Alternative” and “Positive Experience.” For “Alternative” (n=19), participants stated that they found the writing exercise ineffective and in some cases felt it increased their anxiety. Participants also stated they would
rather engage in other activities, such as reviewing course notes. For example, one participant stated, “I am just too nervous to think of doing so before taking exams. I would rather read more review materials, maybe. Lol. (P44)” For “Positive Experience” (n = 7) participants stated that expressive writing calmed them or helped them organize their thoughts. For example, one participant stated, “I think that I may benefit from writing about thoughts before an exam. (P55)”

The most common theme in the social support condition was “Uncomfortable” (n = 29). In this theme, participants stated that they would not like to rely on others or felt it was uncharacteristic for them to broadcast messages for encouragement. For example, one participant stated, “While I would like reading encouraging responses before an exam, I would not like posting to Facebook because this behavior seems attention seeking and slightly annoying in my opinion. (P88)” Another participant stated, “I would not post to Facebook like this again. It’s not something that people do, and such a post is definitely out of place. I would, however, consider using a more passive and ephemeral media like Snapchat or Yik Yak. That has the benefits of not breaking social norms on FB. (P74)” No differences in participant perception of using social media for anxiety support were present between genders or programming experience.

4.3 DISCUSSION

This study investigated how social support and expressive writing impact the state anxiety and solution correctness of open-ended programming problems for students. The results showed that supportive messages from a student’s social network decreased the state anxiety of high test-anxious students by 21% before performing a mentally stressful activity. Further, the results showed that the number of messages (comments and private messages) received correlated with the reduction in anxiety, whereas the number of ‘likes’ did not correlate. They also showed that when completing programming tasks under pressure, supportive messages and
expressive writing allowed high test-anxious students to perform similarly to low test-anxious students. However, expressive writing increased the anxiety of low test-anxious students by 61%, whereas the social support condition did not. Additionally, studying task-relevant materials had no effect on anxiety and high test-anxious students scored lower than low test-anxious students. Though the quantitative data favored the social support intervention, all of the students reported through the surveys that they were uncomfortable leveraging their online social network to elicit support. The discomfort stemmed from the public nature of the posts and concerns about being perceived as attention seeking.

Information disclosure research has shown that disclosing private information is perceived to be inappropriate for public posts on Facebook [5]. Participants may therefore have felt that asking for encouragement was too private to post on Facebook in this study. Additionally, previous work has shown that people perceive risks of being vulnerable when disclosing private information such as negative outcomes [87]. As a majority of the participants in this study were computer science students, the competitive environment of the curriculum may also have led to concerns about how others would perceive them [4]. They may have felt that such statuses could harm relations in group project settings. Further research is needed to understand if participants were uncomfortable with the specific formulation of seeking social support in this study or with seeking social support online generally.

4.3.1 IMPLICATIONS

Different formulations of seeking social support online, such as giving users more control over the audience, ephemerality, anonymity of the requests, and rhetorical strategies should be studied to examine how to increase comfort for students soliciting supportive messages. Lists with only certain members of a user’s social circle could be used to better control disclosure
while still reaching a wide audience. For example, Haimson found that people undergoing
gender transition used private lists that contained a user-selected subset of social ties to manage
their disclosure [35]. Reducing the length of time messages are visible to a social network by
controlling ephemerality could also increase comfort. For example, Xu and colleagues found that
participants had fewer concerns over self-presentation when using Snapchat (which allows
ephemeral messages) compared to other communication tools [85]. Anonymity, such as on Yik
Yak or Facebook Confessions Boards, has been shown to increase comfort as people are more
willing to disclose to strangers [43]. Additionally, different rhetorical strategies have been shown
to effect response rates in online communities [14]. In the context of this study, different
strategies could include the phrasing of the requests and how much information is revealed
pertaining to the request. Future work is needed to test how these formulations would affect
students’ comfort levels when seeking social support online, balanced against the speed, volume,
and quality of the messages received.

Instructors who prefer not to use any social media platform could write and share
supportive messages with students. For instance, students could be reminded of previous
assignments where their performance was commendable. Instructors could also organize course-
restricted online discussions where students could exchange supportive thoughts prior to exams.

The results also contribute to understanding how expressive writing affects the anxiety
and programming correctness of students. Previous work has suggested that expressive writing
increases the performance of higher test-anxious participants on exams, modular arithmetic
tasks, and anagram tasks [61, 65]. The results support this and extend this finding to open-ended
tasks, such as programming. They also extend prior work by showing expressive writing
negatively impacts the state anxiety of lower test-anxious students. By expanding the scope of
measures considered in prior work to also include student perceptions, this study that students with lower test anxiety felt the expressive writing “made them aware of their own anxiety,” and “amplified their nervousness.”

Social association with other participants and experimenter empathy has previously been found to aid in performance on anagram tasks [70]. This work focuses on social support from members of a student’s social network. The findings show that supportive messages from Facebook friends help high test-anxious students score similarly to low test-anxious students on programming tasks. Additionally, the findings extend the literature by showing that reading supportive messages before performing open-ended tasks under pressure decreases the state anxiety of students.

4.3.2 LIMITATIONS

One limitation of this study is that all participants attended the same university and the majority were peers in the same course. Future work is needed to generalize these findings to other courses, exam formats, and university environments. It would also be interesting to test the generalizability of these findings in other evaluative situations, such as in job interviews and programming competitions. Prior work showed that women reported increased anxiety for computer-based tests, whereas men reported decreased anxiety [24]. In the present study, effects of gender or race were unable to be examined due to insufficient sample sizes in the participant pool. Further research is needed to examine how these anxiety interventions affect different demographics.

The study design allowed participants in the social support condition to view their supportive messages before they arrived at the experiment. Participants were asked to refrain from viewing these messages, but it was not possible to be sure that the first time participants
viewed the responses was in the laboratory. Constructing a more artificial study could have controlled this, but this may have limited the ecological validity of the experimental design. Further research is needed to understand if viewing messages more than a few minutes before a testing situation affects student test anxiety and performance.

**4.3.3 Future Work**

There are at least three additional directions of work for reducing anxiety during programming exams. One direction is investigating how anxiety affects the coding behavior of programmers at a more granular level. For example, prior work has shown the feasibility of detecting stress by analyzing mouse and keyboard interaction [39, 49, 80, 83]. Expanding this work to understand how anxiety relates to edit, compilation, and execution behavior could lead to possible targeting of anxiety reduction methods within the programming interface. A second direction for future work focuses on how sharing the benefit that supportive messages had on anxiety and solution correctness could encourage others to adopt the strategy. Tracing how student perceptions change as they view peers seeking support may lead to less reservation around using broadcast messages for support. A third direction is studying how the source supportive messages originate from affect anxiety and performance. For example, investigating how the perception that the messages originate from one’s own social media network versus peers that have completed the exam may provide insight into alternative methods of obtaining supportive messages while reducing the discomfort caused by soliciting them on social media.
CHAPTER 5

PERCEIVED AUTHORSHIP EFFECTS ON ANXIETY
AND PERFORMANCE

In Chapter 4, I demonstrated that supportive messages from social media could be used to reduce test anxiety. However, the practice of impression management on social media led to feelings of discomfort when soliciting such messages for exams. In this Chapter, I compare approaches for students to obtain supportive messages without soliciting them. Drawing upon psychological theories of how the source of information affects perception and behavior, I examine how the perception that identical supportive messages are written by peers, social media ties, or famous people affects the anxiety of students and how well they perform on an open-ended problem-solving task.

In this chapter, I present the results of a study that had three goals: (1) to investigate how the perceived authorship of supportive messages affects the anxiety of students and their performance on an open-ended problem solving task, (2) to understand how the perceived message authorship affects how supportive students report the messages are, and (3) to examine what style of supportive messages students feel are most supportive.

5.1 METHOD

A single-factor, between-subjects lab experiment was performed to investigate the differences in supportive message authorship. The factor was the perceived authorship of the supportive messages (peers vs. social media ties vs. famous innovators vs. control). Participants
were randomly split into groups at each factor level. The instructor of a Spring 2017 Computer Science Data Structures course of 600 students sent an email offering an extra credit incentive for participation and a Google Form. The Google Form asked students to complete demographic information, the Cognitive Test Anxiety Scale, and indicate if they were willing to create a Facebook post asking for support from their social ties. Students received 1% of extra credit for participating and a chance at winning one of six $50 prizes. A total of 214 students participated. I selected this Data Structures course because it had a large enrollment and students in the course had sufficient programming knowledge and experience completing computer-based programming exams.

5.1.1 Participants

Seven-seven percent (77%) of participants identified as men, 20% identified as women, and 3% preferred not to respond. Thirty-three percent (33%) of participants were freshman, 37% were sophomores, 17% were juniors, 8% were seniors, and 5% were graduate students. The average CTA score of participants was 62.4, which is just above the cutoff of 62 for moderate anxiety based on previous work [18]. Half of participants, 49.5% reported being willing to post a message to their private Facebook Newsfeed asking for supportive messages, while the other half 50.5% reported being unwilling to perform the action. Participants who were unwilling to post to Facebook were distributed between the messages from peers, famous innovators, and the control condition. Differences were then examined to understand if those unwilling to post to Facebook were affected differently by the interventions when compared to those willing to post to Facebook.
5.1.2 Open-ended Problems

Students completed two open-ended programming problems using C++. I chose to study open-ended problems because test anxiety is higher when solving these problems and there is a paucity of literature around the effects of anxiety interventions when solving these problems [76, 86]. I chose programming problems because they can be easily and consistently scored using test cases. Additionally, with the spread of computerized testing in engineering, deepening understanding of anxiety interventions for open-ended programming problems would have large implications across engineering. I attempted to keep the programming problems consistent with the study in Chapter 4, however students were asked to participate earlier in the semester than in Chapter 4 thus had less experience with certain programming constructs, such as input streams and binary trees in C++.

Two programming problems were originally chosen. The first was a string rotation problem that required students to write a function that rotated the characters in a string a given number of spaces based on user input. The second problem was a replica of the problem from Chapter 4 and required participants to write a function that removed nodes from a singly linked list if the node’s string data element was longer than a given threshold. A pilot study revealed that students had difficulties with both problems, and thus the first problem was replaced with a problem requiring students to write a function to determine if a given string was a palindrome. Helper functions were provided with the second problem that provided the implementation so that students could print the list and add nodes to the list. The instructions and code for both problems is provided in Appendix B. I selected these problems because students in the course curriculum were expected to be familiar with these concepts. Each problem had many viable
solutions in terms of memory, complexity, and choice of language constructs and participants produced a variety of solutions.

To simulate a real exam, such as those done in their course, students were provided with a source code text editor with the ability to compile and run their code. A pilot study revealed that students took approximately 12 minutes to solve the first problem and 25 minutes to solve the second problem. Additionally, students stated that both problems were appropriate for their level of knowledge.

5.1.3 Supportive Messages

I compared three perceived sources of supportive messages, messages from peers, social media ties, and famous people, against a control condition where participants took a short break. Participants in the experimental conditions viewed messages with identical content, however the messages were revised to increase the perceived authenticity of the messages from each source. In the peer condition, participants were informed that other participants who completed the programming questions at an earlier date authored the messages they viewed. I selected this category because previous work showed when the perception of similarity between the communicator and recipient is high, the greater impact the communicator can have on recipient attitude changes [27, 63]. In the famous people condition, participants were instructed that the messages viewed came from famous entrepreneurs, scientists, activists, and world leaders. This condition was chosen to investigate how generic supportive messages would affect the anxiety and performance of participants. Participants in the social media condition were informed that their social media ties authored the messages they viewed. To convince participants of this, participants in this condition were instructed to make a post to their Facebook Newsfeed one week before the scheduled experiment date. The post instructed Facebook ties that the participant
was competing in a programming experiment and asked them to select a link to a Google Form where they could write supportive messages to the participant. Participants were allowed to modify the template, but were instructed that the link, date of the experiment, and request for supportive messages should all be included. Additionally, the post was to remain visible for at least twenty-four hours. A template of the post can be seen in Figure 5.1.

I’d like your encouragement. I will be competing in a programming competition in a week and as part of the competition, I will be able to view messages from you. Write a short message on the following form: http://bit.ly/2l0T3h8. Any supportive comments would be great to see.

Figure 5.1. The text template used by participants in the social media condition. Participants were asked to post this and leave it on their Facebook NewsFeed for at least 24 hours.

In the Google Form, social media ties could write a supportive message and rate the closeness of their relationship with the participant on a Likert item, where 1 indicated a “Very Distant” relationship and 7 indicated a “Very Close” relationship. The messages and relationship rating were stored in a Google Sheet file that was invisible to the participants, thus participants were unaware of what was said and how many messages they received. A unique identifier was provided for each participant in this condition to distinguish which participants received messages as they were later shared with the participants.

Overall I received 193 Facebook messages from respondents. The average indicated closeness of relationship with participants was 4.87, thus participants had a moderately close relationship with respondents. I used these Facebook messages to create supportive messages for each condition. I chose to imitate these messages because Chapter 4 showed that supportive messages from Facebook were effective in reducing anxiety and increasing the performance of high test-anxious students [25]. This also allowed for the content of the supportive messages to be consistent across participants and conditions.
To create the messages I created themes based on the 193 responses. I first translated four messages from Mandarin to English using Google translate. I then discarded messages that only contained links to images or were nonsensical. Next, I removed any references to names of people or pronouns so that the messages would be anonymous. I segmented the remaining messages into idea units, which totaled 335. I assigned labels to the idea units and iteratively categorized the data to create abstract themes from these labels.

In total I found seven themes from the data: Advise (20%), Predict (18%), Wish Luck (17%), Off-topic/Humor (14%), Praise (14%), Personal Feelings (10%), and Cheer (7%). The Wish Luck theme contained messages focused on words of luck specific for the upcoming programming tasks, such as “Good luck!” The Predict theme contained messages that focused on predicting the participant’s performance on the task or their ability to complete it. For example, messages such as “You can do it” and “Good job” are in this theme. The Personal Feelings theme contains messages that express emotions of the responder, such as “I believe in you” or “I’m so proud of you.” Messages that compliment or praise the participant, such as “You are so smart,” are contained in the Praise theme. The Advise theme is composed of messages instructing participants what to do, such as “Never give up” or “To think outside the box.” The Cheer theme contains messages that are used to root for someone, such as “WOOO!” Finally, the Off-topic/Humor theme contains messages whose intent could not be determined without additionally knowledge of the relationship between the writer and participant. These messages contained swearing, references to past experiences, and humor. I focused on the humor aspects found in the theme to create a message.

I created five unique messages from the themes. These messages were then slightly modified to appear authentic for each condition. Each message contained 2 idea units from the
Advise, Praise, Personal Feelings, Off-topic/Humor, and Cheer themes to replicate the content of messages written by social media ties. The Wish Luck and Predict themes contained messages that were more generic than the other five themes, and idea units from these were distributed among the messages to bolster the supportiveness of the messages. The messages for each condition and the main theme used to construct the message are shown in Figures 5.2 to 5.4.

<table>
<thead>
<tr>
<th>Message</th>
<th>Main Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do your best and remember one competition won’t define your life!</td>
<td>Advise</td>
</tr>
<tr>
<td>You are smart and ambitious. You can do this!</td>
<td>Praise</td>
</tr>
<tr>
<td>I’m so proud of you and I believe in you. Good luck!</td>
<td>Personal Feelings</td>
</tr>
<tr>
<td>They’re afraid I might give you guidance on programming. Haha! I don’t have a clue! Best of luck!</td>
<td>Off-topic/Humor</td>
</tr>
<tr>
<td>WOOOO!!! GO! You got this!</td>
<td>Cheer</td>
</tr>
</tbody>
</table>

Figure 5.2. The supportive messages used in the social media theme.

<table>
<thead>
<tr>
<th>Message</th>
<th>Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do your best and remember this experiment won’t define your life!</td>
<td>Advise</td>
</tr>
<tr>
<td>You are smart and ambitious. You can do this!</td>
<td>Praise</td>
</tr>
<tr>
<td>Your friends and family are proud of you and believe in you. Good luck!</td>
<td>Personal Feelings</td>
</tr>
<tr>
<td>They’re afraid I might give you guidance on programming. Haha! I don’t have a clue! Best of luck!</td>
<td>Off-topic/Humor</td>
</tr>
<tr>
<td>WOOOO!!! GO! You got this!</td>
<td>Cheer</td>
</tr>
</tbody>
</table>

Figure 5.3. The supportive messages used in the peer condition.
<table>
<thead>
<tr>
<th>Message</th>
<th>Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Try your best and remember your work won’t define your life.</td>
<td>Advise</td>
</tr>
<tr>
<td>You are smart and ambitious. You can do anything you put your mind to.</td>
<td>Praise</td>
</tr>
<tr>
<td>Your friends and family are proud of you and believe in you. They will always wish you well.</td>
<td>Personal Feelings</td>
</tr>
<tr>
<td>I don’t know a thing about giving advice. Haha! I don’t have a clue! Best of luck in life!</td>
<td>Off-topic/Humor</td>
</tr>
<tr>
<td>Fight! Go! You can do it!</td>
<td>Cheer</td>
</tr>
</tbody>
</table>

Figure 5.4. The supportive messages used in the famous people condition.

5.1.4 Procedure

Participants followed a similar procedure as in Chapter 4. Participants first completed an online version of the Cognitive Test Anxiety scale two weeks before the lab study and provided demographic information including their gender, year of study, major, and their willingness to post a message asking for support to their private Facebook Newsfeed. A third of participants who stated they were willing to post to their Facebook were provided with a template of a post they were to make a week before their scheduled lab session. The template is shown in Figure 5.1. I oversampled participants for the Facebook condition as I anticipated some participants may forget to make the post and I could change their assigned condition during the lab session if this occurred. The remaining two-thirds of participants who were willing to post to Facebook and the half of participants who were unwilling were randomly assigned to the control, peer, or famous people conditions.

Upon arriving at the study location, the experiment followed the same process shown in Figure 4.4. An experimenter instructed participants that they were competing in a programming challenge and that they would have forty minutes to individually complete two programming
problems. The use of outside resources was prohibited. The experimenter informed them that they would receive 0.5% extra credit for participating and that their were additional incentives based on their performance. The experimenter then instructed participants that if they scored at least a 75% on the programming questions they would earn and additional 0.5% of extra credit, for a total of 1% extra credit. When debriefed participants were informed that the incentives were not based on performance and that all participants received the 1% extra credit. Additionally, participants were split into pairs and were informed that if they and their partner scored an average of a 90% on the programming questions, they both would receive $50. Pairs were assigned based on arrival order and participants were made aware of their partner by raising their hands and making visual contact. All participants were then asked to wait quietly for one minute allowing them to reflect on the presented scenario. The scenario was designed to increase anxiety and was based on previous work [25, 65]. Additionally, a pilot study revealed that participants reported feeling pressured by the added incentive to perform well individually and the pressure to perform well relative to peers. After the minute passed, the state portion of the STAI was administered to measure their anxiety before the intervention.

After completing the state portion of the STAI, participants completed the task for their assigned condition: waiting for 3 minutes (control), reading messages they perceived were from peers, famous people, or social media ties. The messages for each condition are shown in Figures 5.2 to 5.4. Participants were also asked to rate how supportive they felt each message was. I asked this as a manipulation check to see if participants felt the messages were supportive and to gather insight into how participants perceived the various themes of supportive messages. After reading the messages or taking a break, participants completed the state portion of the STAI again as a post measure and then completed the programming tasks. After finishing the
programming tasks, a post-study questionnaire was used for participants to indicate how the intervention helped or did not help their anxiety and if they would be willing to read such messages before a course exam. Finally, all participants were provided with a debriefing form instructing them that they would be receiving 1% of extra credit, regardless of their performance, and they had been entered into a raffle to win one of six $50 prizes.

5.1.5 Measures

I used similar measures as in Chapter 4, using the CTA to measure test anxiety and the state portion of the STAI to measure anxiety in the moment. I classified participants as low anxiety if they scored a 61 or below on the CTA, moderate if they scored between a 72 and 62, and high if they scored a 73 or above. These cutoffs were based on previous work [18]. The ratings indicating how supportive participants felt a message was were made on a seven-point Likert item where 1 indicated “Not at all supportive” and 7 indicated “Extremely supportive.” The post study questionnaire data was collected using a five-point Likert item for the two questions: “[Intervention] helped reduce my anxiety about the programming task,” and “I would use [intervention] before a course exam,” where intervention reflected the condition. I used five-point Likert items to make comparisons to the findings in Chapter 4. Participants provided open-ended responses to support their rating and I coded them using the same method as in Chapter 4. The programming problems were scored using input test cases and ranged from 0 to 100, with code that did not compile scoring a zero. The first problem, writing a function to determine if a string is a palindrome, was worth one-third of the total points and the second problem, the linked list manipulation task, was worth two-thirds of the total points. This point distribution was chosen based on the length of time and work demonstrated by students in the pilot test.
5.2 RESULTS

In Chapter 4, I examined only participants who were willing to post to their Facebook. Participants in the present study were split between those who were willing to post to their Facebook and those that were not. To examine if there was any difference in how these two groups experienced the anxiety interventions an ANCOVA was performed for each condition. The difference between the state anxiety pre-measure and post-measure was the dependent variable, the willingness to post to Facebook was the factor, and the cognitive test anxiety score was the covariate. The control condition showed no significant interaction effect, F(1,51) = 0.13, p = 0.72 or main effect, F(1,51) = 1.32, p = 0.26. In the messages from famous people condition, the ANCOVA showed no significant interaction effect, F(1,56) = 0.57, p = 0.453 or main effect with F(1,56) = 0.76, p = 0.388. Likewise, the peer condition showed no interaction effect, F(1,60) = 0.54, p = 0.47 and no main effect, F(1, 60) = 0.9, p = 0.35. Thus, the data was combined and the factor of willingness to post to Facebook was removed from the model.

A correlational analysis was performed on the anxiety metrics to check that the CTA score correlated positively with the pre-measure state anxiety, meaning students who reported higher levels of test anxiety experienced higher levels of state anxiety after the experimental instructions. The analysis showed that the CTA correlated with the pre-measure state anxiety (r = 0.51, r² = 0.26; p < 0.0001).

To ensure that the participants in each condition were not significantly different from each other, I compared the pre-measure state anxiety and cognitive test anxiety score between conditions. ANOVAs revealed that the conditions showed no difference in pre-measure state anxiety, F(3, 210) = 1.2, p = 0.309 or CTA score, F(3, 210) = 0.24, p=0.87. I also investigated gender effects for pre-measure state anxiety and CTA score because Chapter 3 showed that...
anxiety may be affected by gender differences. The ANOVA’s showed no difference between
genders on pre-measure state anxiety, $F(3, 210) = 0.31$, $p = 0.8166$ or cognitive test anxiety
score, $F(3, 210) = 1.03$, $p = 0.3822$.

To examine if participants perceived the messages as supportive, the average rating of the
messages was calculated. Participants rated the messages moderately supportive, with an average
rating for each message of 4.48 in the famous people condition, 5.17 in the peer condition, and
5.31 in the social media condition. This confirmed that the manipulation of viewing supportive
messages was effective.

5.2.1 Effects on Anxiety

Figures 5.5 to 5.8 show the state anxiety of participants before and after the assigned
anxiety intervention. As shown in the figures, participants in the control and messages from
famous people conditions reported equal pre-measure state anxiety and post-measure state
anxiety. They also show that participants in peers and social media conditions have a higher pre-measure anxiety than post-measure anxiety.

Figure 5.9 shows the means for the difference in state anxiety for each condition. It shows the differences in means for the social media (-2.97), peers (-2.77), and famous people (-1.02) conditions were negative indicating a decrease in anxiety between the pre- and post-measures, and the control condition (0.62) slightly increased in the anxiety of participants. A one-way ANOVA was performed and showed that the difference in means was statistically significant, $F(3, 210) = 5.87$, $p < 0.001$. Post-hoc tests comparisons revealed that the social media and peer condition reduced anxiety significantly more than the control condition ($p < 0.01$, $d = 0.69$ and $p < 0.01$, $d = 0.78$, respectively).
Figure 5.5. State anxieties before (X-axis) and after (Y-axis) the control condition. The dotted line indicates perfect correlation and the solid line is the regression line for the data.

**Control**

![Graph showing state anxieties before and after the control condition.

**Experienced Peers**

![Graph showing state anxieties before and after the peer condition.

Figure 5.6. State anxieties before (X-axis) and after (Y-axis) the peer condition. The dotted line indicates perfect correlation and the solid line is the regression line for the data.
Figure 5.7. State anxieties before (X-axis) and after (Y-axis) the famous people condition. The dotted line indicates perfect correlation and the solid line is the regression line for the data.

Figure 5.8. State anxieties before (X-axis) and after (Y-axis) the social media condition. The dotted line indicates perfect correlation and the solid line is the regression line for the data.
In Chapter 4, I showed that the difference in state anxiety caused by anxiety interventions was affected by cognitive test anxiety level. To examine this an ANCOVA was performed with difference in state anxiety as the dependent variable, condition as the main effect, and cognitive test anxiety score as the covariate. The ANCOVA revealed no significant interaction effects $F(3, 206) = 1.99$, $p = 0.116$. Thus, the two interventions affected low and high anxiety participants similarly.

5.2.2 Effects on Performance

To investigate if the anxiety intervention affected performance, I tested the differences between low and high test-anxious anxious students within anxiety intervention condition. Participants were categorized using the cutoffs found in previous work [18]. Participants scoring less than 62 were categorized as low test-anxious, between 62 and 71 were categorized as moderate test-anxious, and 72 or greater were categorized as high test-anxious. Figures 5.10 to 5.13 show the mean performance for the low, moderate, and high levels of the CTA for each condition. I hypothesized differences in performance between low and high anxiety students. A one-way ANOVA was applied to each condition with the level of anxiety (low or high) as the
independent measure and performance score as the dependent measure. A main effect was found in the control condition, $F(1, 33) = 3.97$, $p < 0.05$, $d = .80$, indicating that low test-anxious participants scored higher on the programming task than high test-anxious participants. This supports previous work that high test-anxious students perform worse than low test-anxious students [19, 65, 86]. To examine if the experimental conditions affected the performance of high-test anxious students, a one-way ANOVA was performed comparing the performance scores of high test-anxious students between conditions. It showed no difference in the performance scores, $F(3, 51) = 2.15$, $p = 0.11$. Thus, performance was not adversely affected by reading supportive messages.

![Figure 5.10. Differences in performance between anxiety levels.](image1)

![Figure 5.11. Differences in performance between anxiety levels.](image2)
5.2.3 PERCEPTIONS

Participants found the messages to be moderately supportive as shown in Figure 5.14. An ANOVA did reveal that messages from peers (u = 5.17) and social media ties (u = 5.31) were perceived as being more supportive than those from famous people (u = 4.48), F(2, 156) = 7.82, p < 0.001. Thus the perception that people that have a relationship with the participant or have similar experiences authored the messages increased how supportive participants viewed the messages. In other words, the authorship affected the feelings of supportiveness even when the content remained consistent.
I also examined if the themes within each supportive message affected how supportive participants rated the message between conditions. Figure 5.15 shows the mean rating for how supportive participants rated each message. An ANOVA showed that the theme of the messages had a main effect on the ratings ($F(4, 624) = 7.93, p < 0.0001$), with no interaction effect ($F(8, 624) = 1.719, p < 0.10$). Ten pairwise t-test were performed as a post-hoc analysis and a Bonferroni adjustment was used so that $p = 0.05/10 = 0.005$. Ratings for the Praise theme were significantly higher than ratings for the Off-topic/Humor ($T(158) = 4.35, p < 0.001$) and Cheer themes ($T(158) = 2.82, p < 0.01$). Also ratings for the Personal Feelings theme were significantly higher than ratings for the Off-topic/Humor ($T(158) = 4.74, p < 0.001$) and Cheer themes ($T(158) = 2.82, p = 0.01$). Lastly, the Cheer theme had a significantly higher rating then the Off-topic/Humor theme, $T(158) = 2.92, p < 0.01$.
Participants rated how the intervention affected their perception of their anxiety in the post-study survey with the question “[Intervention] helped reduce my anxiety about the programming task.” The differences are shown in Figure 5.16. A between subjects Kruskal-Wallis test revealed that a difference was present in how participants rated their perception of their anxiety between condition, $X^2(3,210) = 16.7, p < 0.001$. Post-hoc tests revealed that peers ($u = 3.3, p < 0.01$) and social media ($u = 3.49, p < .01$) conditions were rated significantly higher than the famous people condition ($u = 2.67$) supporting the results found using the STAI as the measure. Participant responses were also similar to the responses provided in Chapter 4 to the same question. Participants also reported their willingness to read such messages before a course exam as shown in Figure 5.17. A Kruskal-Wallis showed that no effect was present between conditions, $X^2(3,210) = 3.72, p = 0.29$. 

![Graph](image_url)
5.3 DISCUSSION

This study investigated how supportive messages perceived to have been authored by notable innovators, social media ties, and peers impact the state anxiety and solution correctness of open-ended programming problems. The results showed that supportive messages perceived to be authored by social media ties or peers with similar experiences decreased the state anxiety of participants by 7%. The results also showed that reading supportive messages from famous
people, peers, or social media ties has no adverse effect on open-ended problem solving performance. Further, supportive messages perceived to be written by social media ties or peers were viewed as 15% more supportive when compared to messages coming from famous people. Additionally, when the content of the supportive messages focused on the praising the participant or personal feelings of the message author, participants found the messages to be the most supportive.

5.3.1 Implications

The results of this study produce several implications. First, the results show that the perception that messages are written by people with knowledge of an evaluative situation or a relationship with the person in the situation affect how people interpret the message. The results that support this were that participants found the messages perceived from peers and social media ties as 15% more supportive than those from famous people, even though the content from the messages were identical. This implication is also supported by the result that messages from peers and social media ties reduced anxiety by 7%, while having no affect on messages from famous people. The benefits of this result include knowledge for students and instructors for whom to obtain supportive messages from for exams or other evaluative situations. Instructors could consider having peers write messages to each other as they have knowledge of the situation. This could also act as an alternative for students who feel uncomfortable soliciting support from their social media.

A second implication of this work is that the content of supportive messages has an affect on how supportive students perceive them. The findings that messages focused on qualities of the test-taker or personal feelings of the message writer were the highest scoring types of messages (5.23 out of 7) support this. Message creators can learn from this result and when
providing emotional support in evaluative situations can focus on reassuring the test-taker of their positive qualities and feelings of the encourager, rather than attempting to provide advice. Instructors can also use this knowledge to create supportive messages that focus on reassurance and could ground the statements from evidence from previous course assignments. For example, an instructor could create a message, such as “You are smart and hard-working and you’ve demonstrated this on your homework assignment where you earned a 95%.” More studies would be needed to understand the affects and scalability of such an approach. This implication is also related to previous work showing that praising children for their effort is more effective than praising their ability [56]. Supportive messages might focus on the effort students have demonstrated rather than complimenting their intelligence.

A third implication is the development of software that enables students to access a bank of supportive messages. The content of the messages used in this study were not dependent on a specific exam. A tool that banks messages that peers write and allows test-takers to access them on demand could provide an anxiety intervention for all students and could be used in other evaluative situations, such as job interviews.

5.3.2 LIMITATIONS

One limitation of this study is that participants were in the same course at the same university. Future work is needed to generalize the findings to other courses and universities. Another limitation is I controlled the number of messages. A moderately positive relationship (r = 0.55) between the number of messages received and decrease in anxiety was shown in Chapter 4. In this chapter, I controlled the number of messages to remain consistent across participant and condition, which limited the potential effects message quantity could have on anxiety. A final limitation is that to remain consistent across conditions with the content of the messages, I
based the messages on real messages written by social media ties. Peers and famous people might write different types of messages with different content. The focus of this study was on how the same content was perceived differently, thus I had to choose how the content of the messages would be constructed. I decided to base the content on social media messages because Chapter 4 demonstrated that they were capable of reducing anxiety for programming exams.

5.3.3 Future Work

I see at least two directions of future work. One direction is examining how repeated exposure to supportive messages before an exam affects the anxiety and performance of students. I examined one instance of using this anxiety reduction strategy and repeated usage might have different affects on anxiety. A second direction is examining how supportive messages could be accessed on demand during the exam process rather than only at the beginning. Allowing students to access messages at anytime during the process might help further decrease anxiety and increase performance. Approaches that allow for supportive messages to be accessed at any time and limit the ability of students to cheat would need to be further examined. Examining when and how often students access messages could also help develop intelligent interventions that notify students with a supportive message when the system detects they need it.
CHAPTER 6
BROAD IMPACT

Test anxiety is pervasive and leads to poor performance on tests [45, 86]. Instructors should consider it when designing exams so they can accurately measure the learning gains of their students. Promoting anxiety coping strategies, such as encouraging the solicitation of supportive messages from social media, could provide one approach to the 22% of anxious students who do not have a method to cope with their anxiety. Instructors might also integrate encouraging messages from peers into the course and testing process to mitigate feelings of discomfort that arise when soliciting messages on social media. Other approaches, including frequent lower stakes exams or providing flexible time for exams in courses could help mitigate the high levels of anxiety students report for tests [3, 31]. Providing practice exams to get students comfortable with the types of questions being asked might also aid in reducing anxiety.

6.1 DISCUSSION

The goal of the studies presented in this dissertation is to encourage instructors, especially those in computer science, to consider approaches for reducing test anxiety in their courses. I demonstrated the pervasiveness of test anxiety for computer programming exams to show that these effects are present in our field. By adopting new testing formats, such as open-ended computer-based programming tests without an understanding of how this affects student anxiety, we limit the accuracy of our assessments. Conducting research in this domain and incorporating anxiety reduction techniques and findings into the exam process can aid in
developing testing situations that assess students accurately and limit student testing concerns to the content of the curriculum. Instructors can provide students with the option to take an exam on paper or on a computer allowing students to select the modality that they are most comfortable with. Informing students of the benefits of social media as a test anxiety intervention can encourage students to step out of their comfort zone to apply method that works. Research demonstrating the positive effects of the intervention combined with the common use of such solicitations on social media for other situations might encourage an increased adoption in this approach.

To incorporate supportive messages into the exam process, instructors could collect supportive messages from students after course exams. They could select messages that are supportive and appropriate (e.g. remove hints or swearing) and use them for future exams. Instructors could also develop messages and distribute them to students. By focusing on messages that praise the test-takers abilities and efforts, instructors could recommend the appropriate style of messages.

In practice a system could be developed to aid in structuring how supportive messages are delivered to students. The survey in Chapter 3 demonstrates that such a system could provide a coping strategy to the 22% of students that reported having anxiety on exams, but no coping strategy. For example, using Facebook classroom pages, an instructor could input the testing schedule for a course and post on behalf of the class soliciting supportive messages. This has the benefit of obtaining supportive messages that were shown to be effective in Chapter 4 and reducing the burden of students soliciting the messages themselves and thus feeling uncomfortable. These messages can then be stored and categorized into unique themes either manually or by using natural language processing tools. Before or during an exam, students
could access the messages through an application that controls the content available to view to reduce inappropriate behavior such as cheating. Students could also improve the quality of the messages by rating how effective the messages were in reducing their anxiety. Additionally, personalization could be integrated by tracking student demographic information along with which messages they view as being more supportive. This can help in understanding gender differences and factor in individual preferences for supportive messages. As Chapter 5 showed, the personalization can also increase the effectiveness of the messages at reducing the anxiety of the students. Additionally, as the messages used in Chapter 5 were not specific to the task, the messages could be reused for different exams and the same messages could be used for the same group of students.

Examining how the interventions presented can be used in conjunction with trained professional sessions is another area to study. The population studied in this dissertation was students not diagnosed with general anxiety disorder. These approaches are not intended to replace seeking professional help when anxiety becomes debilitating, but is rather an option for students with high anxiety that limits their performance and a method to use in addition to professional assistance for those suffering from debilitating anxiety. This approach of using social media as an anxiety intervention might also be used as a signal for the need for professional help with test anxiety. If a student repeatedly requires this intervention and becomes dependent on it, an expert might be able to intervene to diagnose the student and provide more in-depth approaches, such as systemic desensitization or cognitive behavior therapy. Repeated usage of the interventions described might also be a signal of the need for professional help with test anxiety.
With the introduction of anxiety reduction strategies, instructors can also examine how this affects the pervasiveness of cheating. Kouchaki and Desai showed that in evaluative situations, when students experience high anxiety they are 23% more likely to engage in unethical behavior [50]. Reducing the anxiety of students may decrease the likelihood students will cheat, providing more accurate test scores and fewer academic misconduct hearings.

Students can also be made aware of possible and alternate coping strategies for exams. Being informed of the benefits of soliciting supportive messages on social media, including a 21% reduction in anxiety and a 5-7% increase in performance, may encourage more students to practice this approach. Seeing peers use this strategy may also diminish the discomfort student’s feel soliciting messages on social media. For example, the student in Chapter 4 who reported that they would not post to Facebook to solicit support for an exam because “It’s not something that people do…(P74),” may adjust their perception as more students use social media to solicit messages for anxiety reduction. Social norms theory focuses on how human behavior is shaped by shared rules, and social media has demonstrated to be a method to create social norms for groups that share a social identity [33]. Other students reported the method as “attention-seeking.” Recently, Facebook has made changes to make soliciting recommendations more attention grabbing, by consuming more screen space as in Figure 6.1. As this feature becomes more popular, users might feel more comfortable soliciting responses for other situations, such as exams and job interviews.
These studies also have implications outside of testing. Job interviews, especially for software development positions, have moved toward computer-based programming interfaces. Websites such as Hackerrank and Interview Cake allows employers to use their platform to provide timed open-ended programming questions to applicants [17, 66]. Other websites such as Collabedit and Interview Zen allow employers to watch the screen of programmers while they solve programming tasks [21, 42]. These situations have high stakes, time pressure, and lead to higher anxiety for applicants. Soliciting supportive messages before these evaluative experiences could help reduce anxiety. Employers might also consider methods to reduce the anxiety placed on candidates as the high levels of anxiety produced by the situation may lead to inaccuracies in measuring the abilities of candidates. Considering alternative approaches such as providing longer periods of time to solve the problems may help reduce the pressure placed on applicants, reducing their anxiety and increasing the accuracy of the programming questions.
6.2 LIMITATIONS

This work has several limitations. First, the work makes the assumption that students are adequately prepared for the exam and want to do their best. These interventions are not an alternative to preparation, but are for supporting students that are prepared and experience increased anxiety. In these studies, it could be possible that some students viewed participation as only a method of extra credit and were not motivated to put equivalent effort into the programming questions to that of a course exam, but participants gave no indication of this.

Second, in the studies presented, students were led to believe there was a benefit for performing well with increased extra credit and monetary rewards, but the stakes for poor performance were not high. Thus, the experimental setting could not recreate all of the factors that occur in a course exam, such as grade history, personal expectations, and future academic and career opportunity losses. Third, this work focuses on programming exams so it is unclear how the findings might generalize to exams in the humanities, social sciences, and other disciplines where programming is not being assessed. The problems solved in the studies are open-ended, and thus anxiety and performance may be similarly affected on exams that require similar creativity and have multiple correct solutions such as essays or free response problems.

6.3 FUTURE WORK

This work also presents new directions for future work. One direction is studying the effects of repeatedly using encouraging messages as an anxiety intervention. Investigating if messages written by social media ties can be reused to produce a similar reduction in anxiety and increase in performance should be studied. Reminiscing on older messages and photos has demonstrated to be effective in decreasing depression [41]. Additionally, Facebook messages
from close social ties, or about specific situations and experiences, have been shown to be good for reminiscence by Facebook users [22]. Supportive messages may be viewed similarly and could lead to a similar reduction in anxiety and increase in performance. In the long-term, students may be able to remember previous supportive messages for new testing experiences where they do not have access to supportive messages.

The impact repeatedly soliciting supportive messages has on social capital is also in need of further study. Ellison and colleagues studied the relationship between social capital and Facebook communication [26]. They showed how attention-signaling behavior, such as writing a message on a public Facebook Wall, is linked to expectations of reciprocity and access to social resources, such as emotional support, from one’s social media network. Repeatedly asking for support may affect the likelihood that social ties respond, affecting reciprocity and the social resources social ties provide.

A final direction is the creation of technological system that allows students to share preparation methods, coping strategies, and encouraging messages with peers. This system could benefit students throughout the exam process and provide emotional and informational support for students.

6.4 CONCLUSION

Computer-based programming exams present new challenges to students and instructors. The increased anxiety reported by some students [25, 88] and the lack of coping strategies of other students demonstrate the need for effective coping methods. Technology can help provide effective coping strategies by connecting students with their social network or peers and supportive messages can be used to reduce the anxiety and increase the performance of students.
In this dissertation, I make the following contributions: deepen the understanding of the prevalence of test anxiety and coping methods in computer science, demonstrate the effectiveness of using social media to solicit supportive messages as an anxiety reduction method, and demonstrate how the perceived author of supportive messages affect the anxiety reduction of the approach. The implications of these contributions affect students, instructors, hiring managers, and educational testing companies. This work should also be considered when investigating the gender imbalances in STEM fields. This work shows how anxiety is perceived by both genders during exams and reducing anxiety may impact the attrition rate for less represented populations.
REFERENCES


<table>
<thead>
<tr>
<th>Number</th>
<th>Author(s)</th>
<th>Year</th>
<th>Title</th>
<th>Journal/Publication</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>53</td>
<td>Robert M. Liebert and Larry W. Morris</td>
<td>1967</td>
<td>Cognitive and Emotional Components of Test Anxiety: A Distinction and Some Initial Data</td>
<td>Psychological Reports 20, 3: 975-978</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Mark W. Newman, Debra Lauterbach, Sean A. Munsun, Paul Resnick, and Margaret E. Morris</td>
<td>2011</td>
<td>“It’s not that I don’t have problems, I'm just not putting them on Facebook”: Challenges and Opportunities in Using Online Social Networks for Health</td>
<td>Proceedings of the 14th ACM Conference on Computer Supported Cooperative Work &amp; Social Computing, 341-350</td>
<td><a href="http://dx.doi.org/10.1145/1958824.1958876">http://dx.doi.org/10.1145/1958824.1958876</a></td>
</tr>
<tr>
<td>58</td>
<td>Keith Nolan and Susan Bergin</td>
<td>2016</td>
<td>The role of anxiety when learning to program: A Systematic review of the literature</td>
<td>Proceedings of the 16th Koli Calling International Conference on Computing Education Research ACM, 61-70</td>
<td><a href="rg/DOI">rg/DOI</a></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
</tr>
</thead>
</table>
| 9.       | Consider the following statements above and assume the standard iostream library has been included. What is the result of executing these statements?  
Mark only one oval. |
| 10.      | Which of the following describes the abstract data type that operates using a pop and push operation where only the top object can be added or removed?  
Mark only one oval. |
| 11.      | Assuming the standard iosstream and string libraries are included, and you are given the following line of code below. Which of the following prints the string “Jobs” to standard output?  
Mark only one oval. |
| 12.      | What is the average case time complexity of bubble sort and merge sort, respectively?  
Mark only one oval. |
13. Question 5. Suppose that we have numbers between 1 and 500 in a binary search tree and want to search for the number 123. Which of the following sequences can not be the sequence of nodes visited in the search? * 

Mark only one oval.

- 173, 97, 152, 113, 142, 120, 123
- 332, 9, 275, 59, 128, 123
- 452, 301, 101, 119, 157, 123
- 2, 233, 127, 87, 130, 123
- 5, 20, 100, 125, 110, 123

Figure A.1. (cont.)
APPENDIX B: PROGRAMMING PROBLEMS

Given a string you will check if the string is a palindrome. A palindrome is a word that can be written the same forward or in reverse. For example, the string "racecar" is spelled the same way if you read it forward or backward. The word "palindrome" however is not a palindrome as backward it spells "emordnilap."

You should complete the function isPalindrome(string word) in question1.cpp located in your home directory. You should return a 1 if the string is a palindrome and a 0 if it is not. The function should be case-sensitive. You may use main to test your code and you may create helper functions for your solution.

To open the question1.cpp file, you can either double click it in your home directory or use the terminal and use emacs or vim (i.e. emacs question1.cpp or vim question1.cpp) to open the file. You can compile your code by opening a terminal window, navigating to your file, and typing g++ question1.cpp. This will produce a file named "a.out" which you can run by typing "./a.out."

You will be scored using a series of test cases. Programs that do not compile can not be scored and will thus receive no points.

After you complete your program upload it where it says “ADD FILE.”

Hint: The length of a string can be found by calling [string].size() where [string] is your string variable.

Examples:

isPalindrome("Bab") returns 0
isPalindrome("BaB") returns 1
isPalindrome("aaaa") returns 1
isPalindrome("a") returns 1
isPalindrome("") returns 0

Figure B.1. Question 1 for the experiment in Chapter 5.
```cpp
#include <map>
#include <set>
#include <list>
#include <cmath>
#include <ctime>
#include <deque>
#include <queue>
#include <stack>
#include <string>
#include <bitset>
#include <cstdio>
#include <limits>
#include <vector>
#include <climits>
#include <cstring>
#include <cstdlib>
#include <fstream>
#include <numeric>
#include <sstream>
#include <iostream>
#include <algorithm>
using namespace std;

// You should write your code within this function.
int isPalindrome(string word) {
    return 0;
}

// You can use main for testing
int main() {
    int val = isPalindrome("aaaa");
    cout << val << endl;
    return 0;
}
```

Figure B.2. Code for Question 1 for the experiment in Chapter 5.
You have an arbitrarily long linked list of nodes (between 0 and 100 nodes). You are to remove each node from the list that has a string data member longer than an integer threshold, \( t \). You have access to a pointer to the head of the list and the threshold. You need to write the function that will remove the nodes in the list where the data member is longer than the threshold. Your function should return the number of removed nodes. After completion the head pointer should still point to the head of the list (even if this head has changed).

To open the question2.cpp file, you can either double click it in your home directory or use the terminal and use emacs or vim (i.e. emacs question2.cpp or vim question2.cpp) to open the file. You can compile your code by opening a terminal window, navigating to your file, and typing `g++ question2.cpp`. This will produce a file named "a.out" which you can run by typing ".a.out."

You will be scored using a series of test cases. Programs that do not compile can not be scored and will thus receive no points.

After you complete your program upload it where it says “ADD FILE.”

Output Format
Your solution should be written in the removeLongWords method in question2.cpp.

Hint: The length of a string can be found by calling [string].size() where [string] is your string variable.

Example
Given the list Tom-->Sam-->Sara-->Grace-->Billy and a threshold of 3, your function should return 3. This is because the names Sara, Grace, and Billy would be removed as they are longer than 3 characters long.

Figure B.3. Question 2 for the experiment in Chapter 5.
/* Node class */
class Node {
  public:
    string data;
    Node * next;
};

/* You can use this method to add nodes to your linked list */
void add(Node * head, string data) {
  Node * n = head;
  while (n->next != NULL) {
    n = n->next;
  }

  Node * m = new Node();
  m->data = data;
  m->next = NULL;
  n->next = m;
}

Figure B.4. Code for Question 2 for the experiment in Chapter 5.
void print(Node * head){
    if(head != NULL){
        Node * n = head;
        cout << n->data;

        while(n->next != NULL){
            cout << "->" << n->next->data;
            n = n->next;
        }
        cout << endl;
    }
}

/* Your solution should be written in the removeLongWords method. */
/* Do not change the function header. */
/* You can access the length of a string by calling [string_variable].size() */
/* The function should return the number of nodes removed. */
/* You can write and use helper methods if you need to. */
int removeLongWords(Node * &head, int threshold){
    return 0;
}

int main(){
    int threshold;

    //Creates a head node
    Node * head = new Node();
    head->data = "Head";
    head->next = NULL;

    //Reads the threshold from the keyboard
    cout << "Enter the threshold: ";
    cin >> threshold;

    //Passes the head of the list and the threshold to
    //the removeLongWords method. Stores the removed node count in
    //count variable.
    int count = removeLongWords(head, threshold);

    //Prints the count to stdout
    cout << count << endl;
    return 0;
}

Figure B.4. (Cont’d)
APPENDIX C: IRB APPROVALS

Figure C.1. IRB Approval letter for Chapter 3 study.
Office of the Vice Chancellor for Research
Office for the Protection of Research Subjects
528 East Green Street
Suite 203
Champaign, IL 61820

April 14, 2016

Brian Bailey
Department of Computer Science
3108 Siebel Center
201 North Goodwin Avenue
Urbana, IL 61801

RE: The Effects of Writing and Social Support on Test Anxiety before Computer Programming Tasks
IRB Protocol Number: 16723

Dear Dr. Bailey:

This letter authorizes the use of human subjects in your project entitled The Effects of Writing and Social Support on Test Anxiety before Computer Programming Tasks. The University of Illinois at Urbana-Champaign Institutional Review Board (IRB) approved, by expedited review, the protocol as described in your IRB application. The expiration date for this protocol, IRB number 16723, is 04/10/2017. The risk designation applied to your project is no more than minimal risk.

Copies of the attached date-stamped consent form(s) must be used in obtaining informed consent. If there is a need to revise or alter the consent form(s), please submit the revised form(s) for IRB review, approval, and date-stamping prior to use.

Under applicable regulations, no changes to procedures involving human subjects may be made without prior IRB review and approval. The regulations also require that you promptly notify the IRB of any problems involving human subjects, including unanticipated side effects, adverse reactions, and any injuries or complications that arise during the project.

If you have any questions about the IRB process, or if you need assistance at any time, please feel free to contact me at the OPRS office, or visit our Web site at http://oprs.research.illinois.edu.

Sincerely,

Michelle Lore, MS
Human Subjects Research Specialist, Office for the Protection of Research Subjects

Attachment(s): Online informed consent document; Waiver of Documentation of Informed Consent form; and Waiver or Alteration of Informed Consent form

c: Robert Deloatch

Figure C.2. IRB Approval letter for Chapter 4 experiment.
Figure C.3. IRB Approval letter for Chapter 5 experiment.