

Psychological Stress and Physiological Reactions:
How Both Affect Cognition

Interactive Qualifying Project

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Abstract

Stress is strongly implicated in both physical and psychological health problems. As noted by Sapolsky (2004), disruptions of homeostasis cause a stress-response, and the stress-response can lead to stress-related diseases. These negative aspects of stress on health are commonly the focus of research. Of particular interest are the physiological effects of stress, and how it affects the body and mind. Social stress in particular is one of the most well-known and robust factors for physiological reactivity. A well-known paradigm to induce acute social stress in a lab setting is the Trier Social Stress Task (TSST; Kirschbaum, 1993), which includes a timed speech and math task in front of evaluators. The TSST reliably as social evaluative stress and physiological reactivity (for review see Dickerson & Kemeny, 2004).

Social stress subsequently affects cognitive performance, as evinced in previous studies involving stress and memory (Kuhlman, 2005). To investigate both the psychological and physiological influences of social stress on cognitive performance, related factors must also be assessed. For college students, variables such as student year, social feedback condition, and social support could affect cognitive performance all in different ways. With these factors in mind, how does stress affect freshmen as opposed to seniors?

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There is a wealth of evidence explicating the biochemical, physiological, and behavioral changes that are associated with stress (Bruns, 2016). The literature on acute stress, of which social stress is classified as, can be measured by the steroid hormone, salivary cortisol, the gold standard of assessing acute stress in a lab setting (Kirschbaum, 1993). The Trier Social Stress Test (TSST) is a standardized experiment that consistently induces a stress response in the hypothalamus-pituitary-adrenal-axis (HPAA), resulting in significant increases of cortisol in the saliva (Kirschbaum, 1993). Findings have also shown that there is a relationship between stress and cognitive control (Plessow, 2011).

While there have been previous studies on how acute social stressors affect cognitive performance, none were found that specifically targets college students. Students in college have both a wide range of social support and daily stressors that could reveal differences in how stress is managed. Specifically, factors of student year and college experience have not been explored in their relation to stress and cognitive performance, critical to high-performing college students.

Stressors for College Students and Acute Stress

The goal of this project has been to determine the psychological and physiological influences on cognitive performance before and after an acute social stress task, by assessing salivary cortisol levels at three assessment occasions and with continuous cardiovascular indices. The primary factor of interest has been the college status of each student. It was hypothesized that there would be statistically significant differences in the acute stress response and subsequent cognitive performance of freshmen and seniors versus that of sophomores and juniors. Freshmen could have a more negative response due to the shock of being in a new place

with new expectations and limited social support from not knowing many people. Seniors, while more likely adjusted to their college environment, may have high stress levels because of facing uncertainty in the prospects of their future - job searching, moving to a new environment, and independence. Alternatively, self-reported survey data may contradict with this idea and portray freshmen on the lower end of the stress spectrum with seniors enduring a higher level depending on these various reported factors. Determining which factors cause or alleviate the most stress could be used to create programs and spread knowledge that helps students better manage stress.

Stress has been extensively investigated due to its debilitating effects on mental and physical health (Bruns, 2016; Sapolsky, 2004). The American Psychological Association (APA) now defines stress as “any uncomfortable emotional experience accompanied by predictable biochemical, physiological, and behavioral changes” (Alvord, 2016). Stress is created by stressors, which O’Brien (2017) defines as “the events that trigger our stress response, because they are perceived/appraised as overwhelmingly challenging, threatening, and/or harmful.” Stress is generally considered to be associated with negative states and its effects are broadly considered deleterious (Bruns). Acute stress can be characterized as exposure to short term stressors - and the effects of acute stress can include but are not limited to muscle tension, nausea, psychological damage, increased sympathetic nervous system activity, increased respiration, and increased heart rate (Alvord). Chronic stress, as opposed to acute stress, is long-term exposure to stressors, and magnifies the effects of acute stress, commonly resulting in major, long lasting health problems such as insomnia, high blood pressure, muscle pains, high blood pressure, and a weakened immune system (Bruns). Acute stress can be measured by the hormone cortisol, which can be obtained from saliva for acute assessments using the Salivette system.

The Trier Social Stress Test

The Trier Social Stress Test (TSST) is a seminal laboratory stress task originally designed by Kirschbaum, Pirke and Hellhammer in 1993. To date, it is one of the most reliable methods of inducing social stress and subsequently creating meaningful changes in salivary cortisol levels, all while in a controlled lab setting. It is considered high in both experimental and mundane realism. The protocol of the TSST involves the participant performing a speech and mental arithmetic task, each task for 5 minutes, in front of a panel of two confederate “evaluators.” The participant is instructed that their performance will be audio-visually recorded for later analysis of performance and non-verbal body language. The evaluators are trained research assistants who are scripted to behave in a stoic or aloof manner and to give little facial and non-verbal feedback to the participants in one condition; in the present study, we also investigated a second condition in which, evaluators begin to offer positive nonverbal feedback approximately 30 seconds into the participant’s performance. The tasks are designed to be difficult and elicit acute stress in the participant, but in a controlled lab environment, where psychological and self-reported data on mood and performance data can be collected (Kirschbaum 1993, Birkett 2011, Dickerson & Kemeny, 2004).

Literature Review and Goals of Stress Management

The relationship between psychosocial stressors and long-term health detriment is affected by the nature, frequency, and magnitude of the stressors, as well as by the individual's biological vulnerability (i.e., genetics, constitutional or dispositional factors), psychosocial resources, and learned patterns of coping (Schneiderman, 2005). Learning coping methods and strategies could provide valuable help in mitigating future stressors. Additionally, psychosocial interventions have proven useful for treating stress-related disorders and may influence the

course of chronic diseases (Schneiderman, 2005). It is important to note that psychosocial factors are modifiable and attainable to any college student. If coping methods are to be investigated to illuminate how students can reduce stress levels, said research may suggest that students will benefit with better cognitive performance when exposed to acute stress.

Physiological stress reactivity is a response generated by an organism from a stressor such as an environmental condition. Some examples prone to induce stress are fear and social anxiety. In humans, stress is the body's method of reacting to a challenge or threat. One physiological response related to stress is innervated by sympathetic nervous system (SNS) activation, which usually results in the fight-or-flight response. Because the body cannot keep this state for long periods, the parasympathetic system returns the body's physiological conditions to homeostasis (McEwen, 2000).

Acute stress can be beneficial as it allows the hypothalamic-pituitary adrenal axis (HPAA) and the SNS to maintain balance and remain active, garner resources to interface with stress, similar to the way in which an influenza vaccination is created from the influenza strand itself. However, cumulative to acute stressors are generally expected to be unhealthy for any individual. Chronic stress can be caused by a change in eating or sleeping habits and from continuous stressors such as work or school. The negative effects of chronic stress can range from muscle and joint pain to high blood pressure and lowered immune system effectiveness.

Specifically, the conducted research examined the cognitive effects of stressors in our daily lives. Several studies of a similar nature have been conducted and displayed results showing that there is decreased memory performance in groups who are more stressed as compared to the control (Kuhlman, 2005).

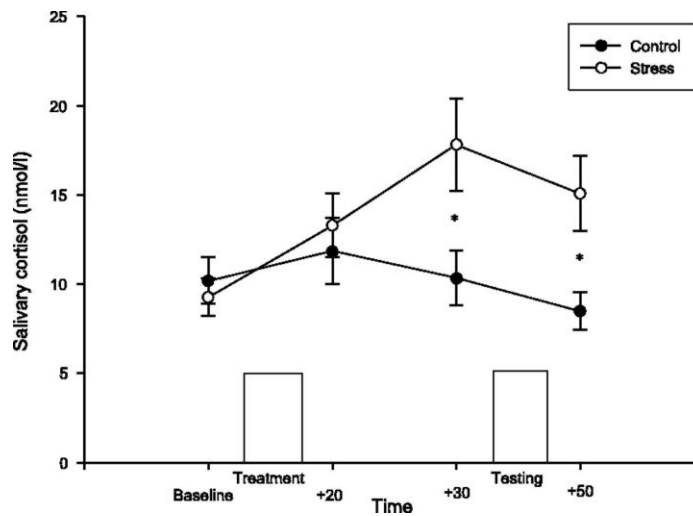
Hypothetical Results

Figure 1: Free salivary cortisol levels in response to the stress or the control condition.

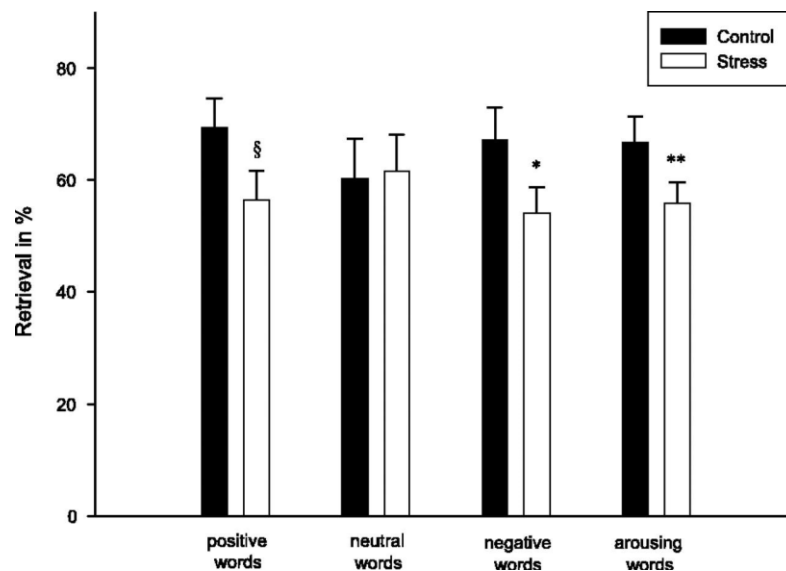


Figure 2: Effects of the stress versus the control condition on delayed memory retrieval

The data presented above compared young healthy males aged 19-40 years old and shows a negative performance in the individuals who underwent the stressful situation. This study demonstrated the cognitive performance through delayed memory recall in participants that underwent either a stressful situation or a control situation. While this is only one study, it

provides a thorough background showing that cognitive performance is negatively impacted by acute stressors.

In summary, it is predicted that heart rate, breath rate, and pulse will be increased during the TSST period for all participants, and that the cortisol levels will be higher in college freshman and seniors than in sophomores and juniors.

Method

Participants

The present study was conducted at the Worcester Polytechnic Institute (WPI), with a student population including 60% male and 40% female. The final sample size (N) = 49 young adults (18 - 22 years of age, 36.7% female), with individuals of varying class years (use specifics: 41.2% freshmen, 17.6% sophomores, 15.7% juniors, 21.6% seniors). Participants completed a prescreening before the study in order to determine their eligibility. Students learned about this study through research requirements provided by the several psychology course offered during the academic year at WPI.

Biological Measures

A tape measure is used in this study to determine the Waist to Hip Ratio (WHR) of the participant. A Blood Pressure Cuff is used at four assessment occasions. A lead II ECG configuration was used to assess continuous cardiovascular indices; a finger photoplethysmogram obtained continuous pulse, and respiration belt were used to assess physiological reactivity. Salivary cortisol is measured using the Salivette system which are taken at three points throughout the study to gather data about cortisol levels of the participant

Psychosocial/Sociodemographic Measures

The Positive and Negative Affect Scale (PANAS; Tran, 2013) is administered at several

points during the study to gain insight into the participant's current mood. This scale lists approximately 20 emotions that the participant may be feeling at any point. To measure cognitive performance a cognitive battery is administered; which includes a backcount (count backwards from 100 for 30 seconds), Digit Span (memorizing strings of numbers of varying lengths both forwards and backwards), Weschler Adult Intelligence Scale (WAIS; Holdack et al., 2011) Vocabulary (Providing definitions for provided words) and Logical memory (Memorization of a story). To apply the stressor, the TSST is run where two evaluators sit behind a desk and have the participant give a five-minute speech for a hypothetical job interview, and have the participant perform a difficult mental arithmetic task. To determine how a participant views his or her social support network or standing at college in addition to his or her acclimation to the college lifestyle, the following surveys are administered: College Readjustment Survey (CRAS), Social Status Ladder (Operario et al.) and Social Support Questionnaire (SSQ; Sarson et al., 1987).

Procedure

After obtaining informed consent, the experimenter then attaches electrodes connected to the Electrocardiogram (ECG) module, breathing belt, and finger pulse module and begins the cardiovascular data acquisition (CV) which relays data to a graphical user interface on the lab laptop. Physiological measures were acquired with an ADInstruments advanced research system T26 bioamp and LabChart 8 software (AD Instruments, CO). On the provided log sheet, the RA records an initial blood pressure and WHR. Additionally, the participant fills out the first of four Positive and Negative Affect Scale surveys and supplies the first salivary cortisol sample. The experimenter then leaves the room to allow the participant to sit silently for approximately five minutes to acquire the subject's resting CV baseline.

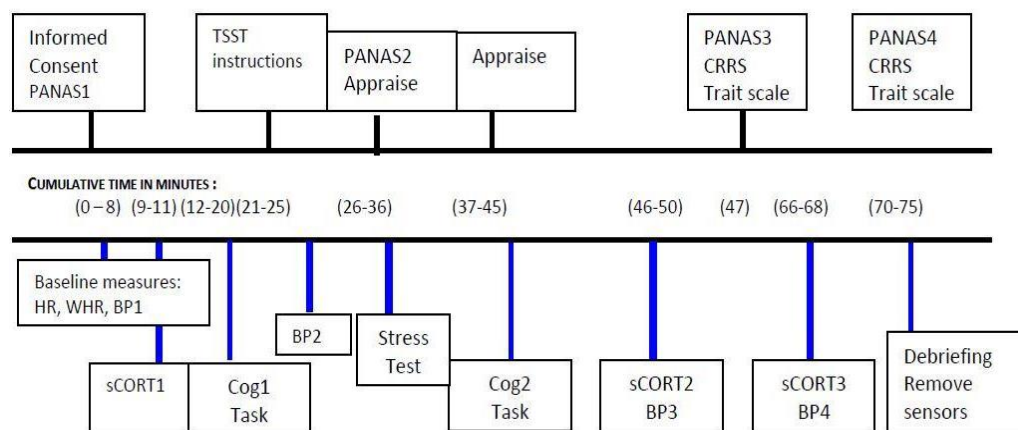
The experimenter explains and administers the cognitive battery test, ensuring the participant fully comprehends the trial before commencing. In this battery, the WAIS vocabulary, logical memory, digit span, and the 30-second back count tasks are performed. The experimenter then informs the participants of the first part of the TSST. This part of the study involves the experimenter instructing the participant that he or she has two minutes to gather thoughts on a provided prompt. They are informed that they are to deliver a five-minute speech to a trained panel of evaluators (confederate research assistants) skilled in reading body language. The prompt is identical for all participants: to imagine that they are interviewing for a personally desirable employment position. For the presentations, participants are asked to describe personality characteristics that would make them the perfect candidate. After the presentation of the task's instructions, the second blood pressure measurement is taken.

Evaluators of the TSST task are trained to provide either stoic (no/neutral facial or bodily feedback), or positive (encouraging feedback after the first thirty seconds of the speech task, positive facial expressions, non-verbal bodily feedback) social responses or feedback. The portion of the study is recorded by use of a video camera for later affective visual or auditory data scoring. Additionally, an unplugged microphone is set up to help frame the setting.

The participant is escorted to the test area where this portion of the experiment can be conducted. The experimenter explains the procedure once more, in detail. The participant is also formally informed that the performance will be visually recorded for later analysis of nonverbal changes in behavior. In reality, the performance is not recorded. After the two-minute mental preparation period, the experimenter returns. The participant takes pre-interview appraisal to gauge how they view the upcoming task: as a threat or challenge. Once completed, an evaluator instructs the participant to move toward the microphone and to begin speaking.

Immediately following the speech task, one of the evaluators will instruct the participant to participate in a math task in which he or she must count backwards from 2043 in steps of 13 for a duration of five minutes. When the participant incorrectly counts a number in the reverse sequence, they are instructed to start over from 2043. If the subtraction proves to be too strenuous, the evaluators are obliged to offer the participant the option to subtract steps of 7. When finished, the experimenter comes back to the test and returns the participant back into the main testing site. The experimenter administers the post-task appraisal and the third of four PANAS surveys. In parallel, the evaluators also complete an assessment rating the levels of perceived anxiety demonstrated by the participant. Once those surveys are completed, they second salivary cortisol and third blood pressure measurement is taken. Additionally, the second set of cognitive battery assessments is administered, excluding the WAIS vocabulary. At the conclusion of the battery, final surveys will be administered to collect data corollary to social support and status including the College Readjustment Rating Scale, Social Status Ladder, and a Social Support Questionnaire. During this time, the final salivary cortisol (20 minutes after the TSST begins) and fourth blood pressure will be obtained.

Figure 3: Hypothesized timeline for study (O'Brien, 2016)



The experimenter then moves into the debriefing period. It is imperative to pay particular

attention to the discussion that occurs when the experimenter inquires about the participant's emotional response to the Trier. During the debriefing, all three RAs (the experimenter and the two evaluators) join the debriefing discussion. In this ending portion, they explain in detail, the TSST procedure and deception that may have been required during the study. Additionally, they are tasked to fully disclose that the intention of the TSST experience was designed to be difficult and at times frustrating. The panel will further reveal that none involved are professionally trained observers, and have not drawn any conclusions from the participant's performance. In closing, the participant should affirm that he or she is mentally stable and emotionally composed enough to leave the study. He or she is then required to fill out one more PANAS survey before being provided a contact sheet for the study. Data is then aggregated for statistical analyses.

Results

Preliminary analysis of both the physiological data and sociodemographic data has provided significant and interesting, albeit unexpected results. Many of the significant results found were based on sex differences - which were not accounted for in the hypotheses.

The first significant result is that consistently throughout the study, blood pressure means in males are much higher than in females, ranging from about 15-17 mmHg for each of the four blood pressure measurements. Do note that the sample size of men to women is uneven – with men making up 63.7% and women making up 36.7% of the total (figure 4 A-D).

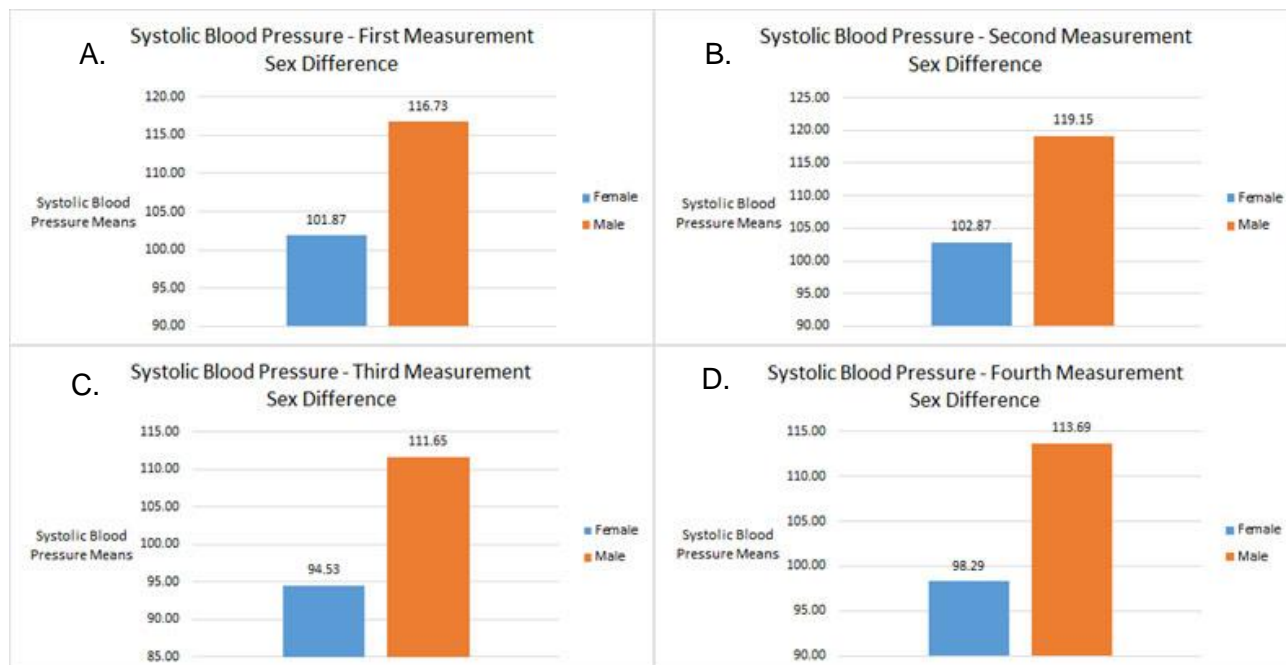


Figure 4 A-D: Systolic blood pressure at four points during the study by sex.

- A. First blood pressure measurement – taken after informed consent.
- B. Second blood pressure measurement – taken in between the TSST instructions and the TSST.
- C. Third blood pressure measurement – taken 20 minutes after the TSST speech task (usually right after second cognitive battery).
- D. Fourth blood pressure measurement – taken right before or during debriefing.

The next significant result is the preliminary analysis of the salivary cortisol data. The estimated marginal means of the second cortisol measurement, seen on the right, show that mean cortisol levels for college upperclassmen (years 2-4) - sophomores, juniors, and seniors, is much higher than that of freshmen (figure 5).

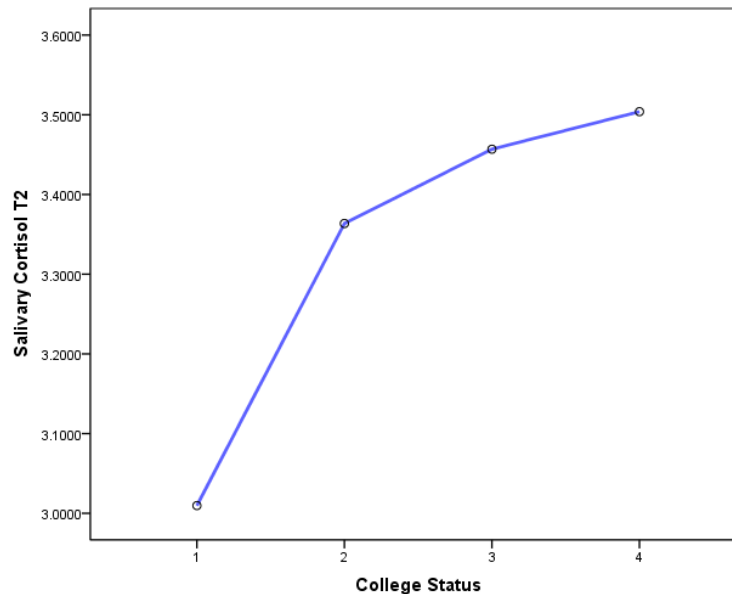


Figure 5: Second cortisol measurement levels by college status.

The next set of findings are how certain measures of the Perceived Stress Scale (PSS) relate to college status and sex. First is the mean scores of the College Re-adjustment Scales (CRAS) - one of the measures used to self-report PSS levels. Senior students' scores are significantly higher than other class years (figure 6). Another significant result is observed when PSS scores in general (all of the surveys and self-reports) are compared between gender. Most notably, that the perceived stress of upperclassmen females is much greater than that of males, and the opposite is the case with freshmen (figure 7 and 8).

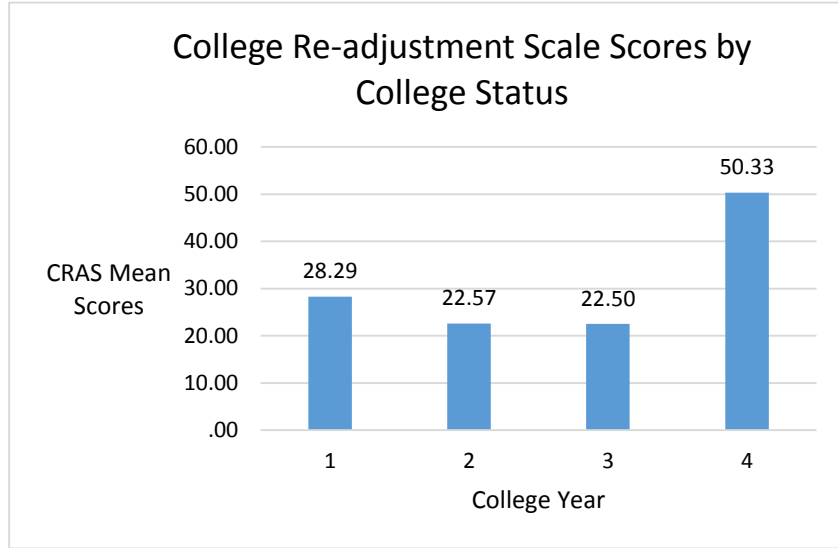


Figure 6: CRAS scores by college status.

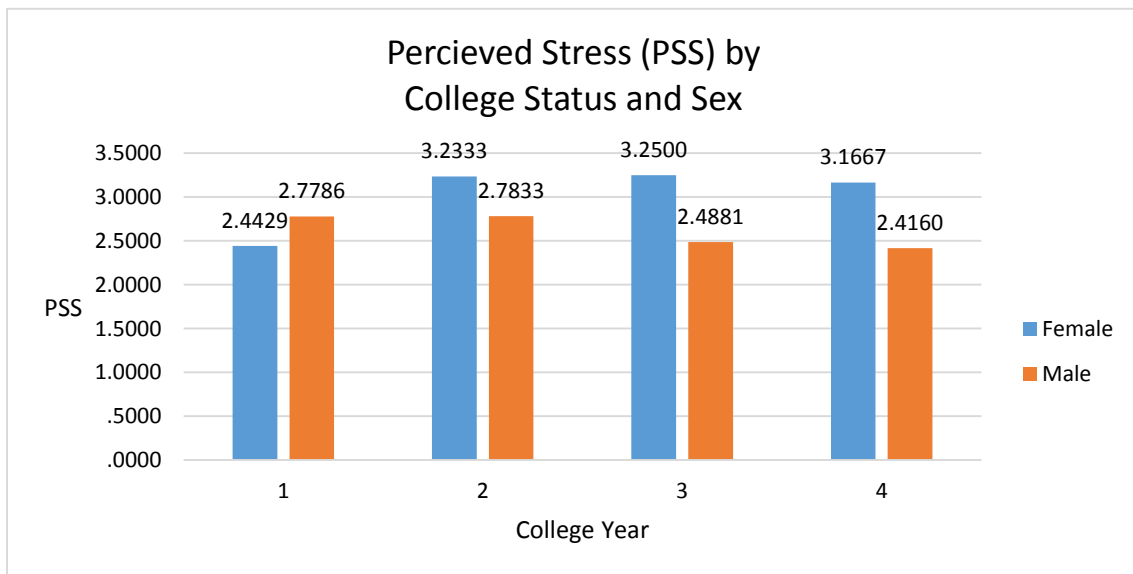


Figure 7: PSS scores by college status and sex – bar graph.

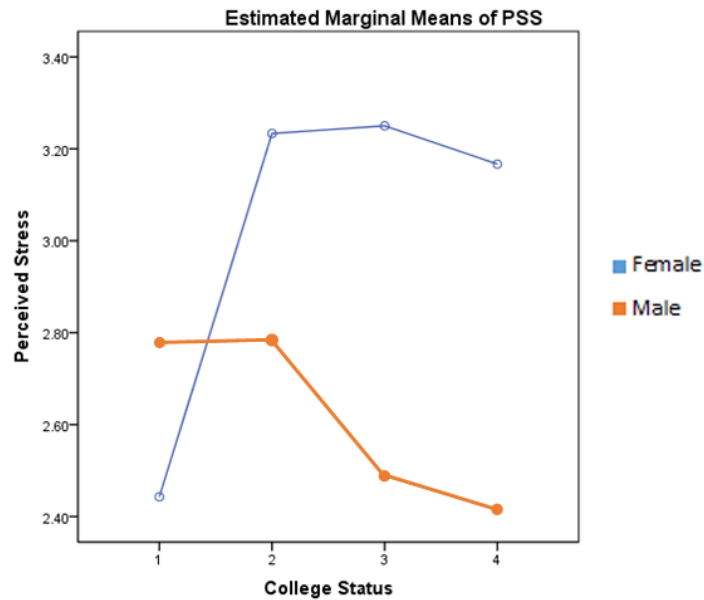


Figure 8: PSS scores by college status and sex – scatterplot.

The last significant finding related to perceived stress is that there is a moderate positive correlation ($r^2 = 0.476$) between negative affect of the PANAS scores and the levels of cortisol from the first measurement. This means that the more negatively affect reported, the higher their cortisol levels (figure 9).

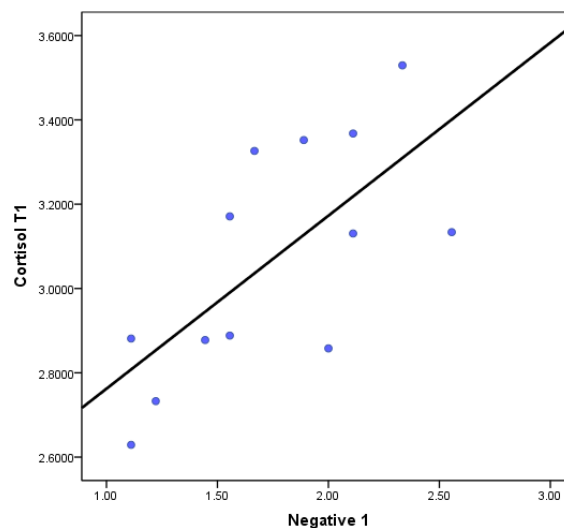


Figure 9: Correlation of negative PANAS affect to first cortisol measurement.

The next models assessed the positive and stoic conditions of the TSST as well as other areas in the study itself – specifically breath and heart rate during the second cognitive battery and TSST speech task respectively. Respiration rate mean during the second cognitive battery were significantly higher in the stoic TSST condition than the positive one (figure 10). Likewise, mean heart rate during the TSST speech task were significantly higher in the stoic condition than the mean heart rates in the positive condition (figure 11).

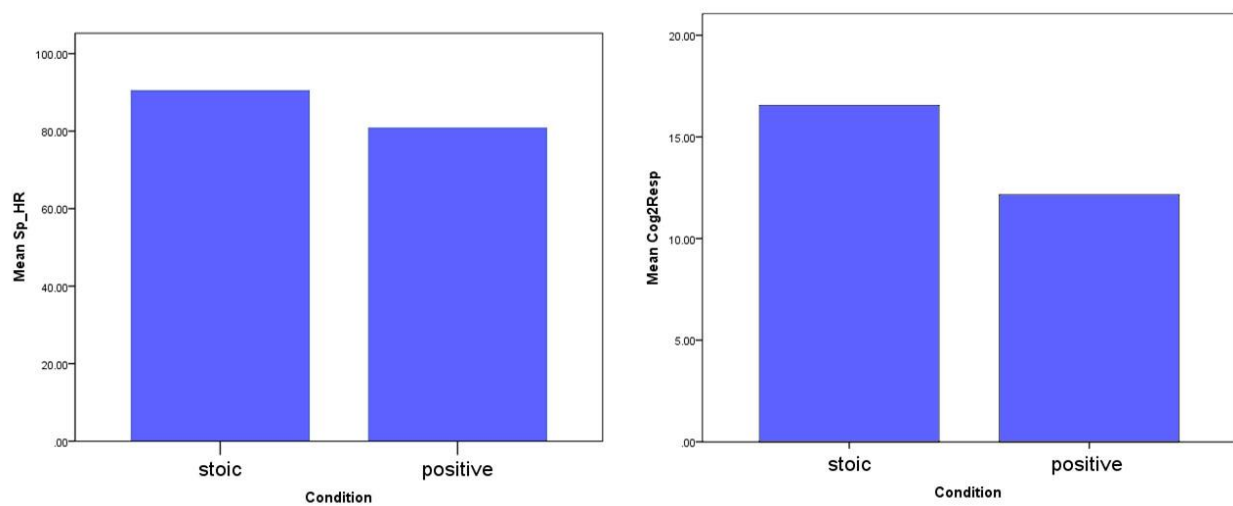


Figure 10 (left): Mean heart rates by TSST condition during TSST speech task.
Figure 11 (right): Mean breath rates by TSST condition during cognitive battery 2.

Discussion

Blood Pressure by Sex

Due to the difference being consistently higher throughout the study including the baseline measurement, the difference can likely be attributed by biological gender differences in that men, on average, tend to have higher baseline systolic blood pressure than women (Reckelhoff, 2001).

Cortisol by College Status

While it was anticipated that seniors' mean cortisol levels would be high due to stress about their futures and job searching, the results remaining three class years do not support the hypothesis that freshmen's cortisol levels would be about as high as seniors, and that sophomores and juniors' cortisol levels would be lower than freshmen and seniors. Many factors could be attributed to this result - stress about projects, or increasing difficulty in classwork perhaps.

PSS, CRAS, and PANAS

Once again, the hypothesis that seniors have higher stress levels was supported, and the cortisol data corroborates that conclusion. What does not support the hypothesis is again the remaining class years' PSS levels. If the results were to hypothetically follow the cortisol data, then the perceived stress levels of sophomores and juniors should be much closer to that of the seniors', however, the case here is that sophomores and juniors perceive their stress to be much lower than what their physiological responses to stress reveal.

The result that female perceived stress levels are much higher than male (except in the opposite case for freshmen) could be attributed to a myriad of factors. One interpretation could be pressures of working in a possibly male dominated work or school environment.

The PANAS scores negative aspect having a significant positive correlation to cortisol levels can lead to the very likely conclusion that a more negative based mood or existing stress when coming into the experiment causes higher cortisol levels.

Physiological Responses by TSST Condition

The increased respiration in the second cognitive battery and the increased heart rate during the TSST speech task can likely be attributed to the participant in the stoic condition

perceiving the experiment as more hostile - causing a slight activation of sympathetic nervous system in the form of increased respiratory and heart rate.

Future Directions

While conducting research and analyzing data in the SHP Laboratory, we continuously assessed data collected to adapt the IQP objectives to target specific demographics and stipulations that may correlate to stress levels of students at WPI. Based on these preliminary results and self-reported survey data, Freshmen may respond more positively due to a lighter course-load and more support from advisors, while upperclassmen typically have schoolwork that is more difficult and less access to advisors. Additionally, Freshman are exposed to the Insight Program at WPI as soon as New Student Orientation begins which serves as a support network to help the first-year students grow and adapt to the college lifestyle. Throughout a student's career, academic difficulty and responsibility for various external factors (i.e. finding jobs, performing well on projects) increase, which in turn could lead to many students losing touch with the initial support group. Further research will need to be conducted in order to fully explore these speculations.

Conclusion

While the preliminary findings of the study do not show conclusive evidence that various stress factors affect a particular class year more so than another (i.e. seniors vs freshmen), trends have begun to form in the data to show that the Senior class at Worcester Polytechnic Institute may be enduring a higher rate of acute stressors. If exposed to these factors for an extended period of time, the culmination of all stress will be deleterious to an individual's health by causing him or her to remain in a perpetual state of physiological distress. Although the project's focus was comparing the stress of specific class years, generally research was conducted under

the impression that stress levels are elevated on a college campus. Throughout the study, data showed that this was true and that universities throughout the world need to be mindful enough to provide the proper resources for students to enable healthy stress management techniques.

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