STUDENT HORMONAL RESPONSES IN TWO LEARNING ENVIRONMENTS

HONORS THESIS

Presented to the Honors College of
Texas State University
in Partial Fulfillment
of the Requirements

for Graduation in the Honors College

by

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San Marcos, Texas
May 2019

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ACKNOWLEDGEMENTS

This thesis would not have been possible without the help of a lot of wonderful people. I would first like to thank the Texas State University Honors College and all their faculty and staff, especially Dean Heather Galloway, Associate Dean Peter Tschirhart, and Dr Ron Haas, for giving me the opportunity to formulate and undertake this thesis project.

My eternal thanks to the Houston Livestock Show and Rodeo and Texas 4-H for their generous funding of my undergraduate education through the Houston Livestock Show and Rodeo Texas 4-H Scholarship. I would like to especially thank Dr Chris Boleman, former Assistant Director for 4-H and Youth Development for Texas A&M Agrilife Extension, for guiding me through the scholarship process and inspiring me and countless other Texas 4-H members to go out and Make the Best Better.

I owe a great deal to Drs Kristy Daniel and Mar Huertas for their leadership and guidance throughout this thesis project, and to their respective labs, who have helped me collect and analyze data, communicate my ideas effectively, and stay sane. Special thanks to Jenn Idema, Victoria Reyes, Zach Nolen, and Bria Marty from the Daniel Lab, and to Jim Hanna from the Huertas lab. Dr Dittmar Hahn and Dean Christine Hailey deserve a huge thanks for their advocacy for this project as well.

I must also thank Dr Joel Bergh for his cooperation and assistance in this project, and all of the volunteer BIO 1330 students who gave me saliva samples each week. Without them, this project would not have been possible at all.

Joseph Plappert, Rebekah Rylander, and Quentin DiPasquale all supported me along the way, as did my parents, Gerard Mac Crossan and Dr Elizabeth Mac Crossan, and my sister, Helena Mac Crossan. Dr M Greg Abel, Dr Bob McLean, Dr Wendi David, and Dr Joel Gray also supported my endeavors and deserve recognition.

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ABSTRACT

Novel classroom spaces are replacing traditional lecture halls as a common initiative to create environments that are more student centered. It is important to investigate how these spaces affect student outcomes. We measured the amount of cortisol, a salivary stress biomarker, in students who participated in an introductory biology course taught in either a traditional lecture hall or a SCALE-UP (Student-Centered Active Learning Environment for Undergraduate Programs) classroom. We hypothesized that students taking the course held in the SCALE-UP classroom would have lower cortisol levels and higher academic performance than students taking the course in the traditional lecture hall. We used a matched sample design to compare cortisol levels and self-reported stress over the course of seven weeks. We also compared average exam scores and student attendance between the course sections. In this preliminary study, we found that there was no significant difference between self-reported stress or mean exam scores between sections. Thus, the classroom learning environments themselves have not significantly impacted self-perceptions of stress nor academic performance so far. This is an ongoing study, and we are running a two-factor ANOVA to compare cortisol levels across section and time, and calculating two Pearson's correlations to determine if there was a relationship between cortisol level with self-reported stress and with academic performance. Upon completion of cortisol analysis, we will better understand the underlying physiological responses of students within different learning environments.

Introduction

Educational reform (e.g., AAAS, 2010) has pushed the notion of reconceptualizing how we should be teaching introductory science at universities. Such reforms stress the importance of active, student-centered instruction. One way that universities have responded to such reform calls is through investments in redesigning classroom spaces in ways to support active-learning associated teaching pedagogy. These classrooms deviate from the traditional lecture halls to which students are typically accustomed. Such deviations may impact student stress, thus impacting learning outcomes. However, no one has yet investigated the physiological responses of students in these new learning environments or how these responses may impact learning outcomes.

The purpose of this study is to understand students' self-reported and physiological stress responses to changes in a learning environment, isolated from pedagogy. We anticipate furthering understanding of the limitations of redesigning spaces, the importance of physical spaces when considering pedagogy reform, and the impacts of stress and the related physiological changes on academic performance in introductory biology courses.

Literature Review

Evidence gathered from active-learning related practices has indicated that active learning has a positive impact on student satisfaction and academic performance in higher education (Prince, 2004). Education researchers have studied the positive impact of active learning curricula (Lucas, Testman, Hoyland, Kimble, & Euler, 2013) and group-focused learning (Williams, 2017). However, little focus has been given to the impacts of physical space on student performance. Research shown that redesigning educational spaces is integral to the success of active learning strategies (Neill & Etheridge, 2008), which has guided universities and other learning institutions around the world to invest millions of dollars in cutting-edge building design that facilitates technological integration and active learning techniques.

SCALE-UP (Student-Centered Active Learning Environment for Undergraduate Programs) classroom design helps to bridge the gap between physical space and active learning techniques (Beichner et al., 2008). These new spaces, which are designed for large-enrollment classes, allow students to sit in small groups at tables—they do not all face the same way, nor are they in rows, which destroys the zonation of the traditional lecture hall. In a traditional lecture hall, there is a relatively small area of the classroom that helps students to achieve their full potential for academic performance in the course (Park & Choi, 2014). SCALE-UP design is specifically intended to facilitate students working in groups, having access to computers and other equipment, and participating in discussions (Beichner et al., 2008). Designed first for science courses, SCALE-UP spaces, pedagogy, and materials aim to facilitate integration of lab and lecture experiences in order to shift the burden of hands-on experience from wholly lab-based to shared between the two environments (Beichner et al., 2008).

Although research has been done on the need for new classroom design, few have analyzed the effects of classroom design on students' stress responses (Lei, 2010). Research has shown that stress in teachers can enhance stress in students and vice versa (Oberle & Schonert-Reichl, 2016), but there is little conclusive information about the impacts of seating arrangements or other spatial elements of the classroom on stress levels of either group. More studies have been undertaken concerning office design than classroom design, and those studies tend to show that the aspect of design with the greatest effect on stress, institutional belonging, and productivity is the layout of the furniture in the workspace (Sadatsafavi, Walewski, & Shepley, 2015; Vischer 2007). However, these findings may easily be extrapolated to students in the classroom, who require the same basic functionalities in a space as office employees. Therefore, it is expected that the rearrangement of a classroom from rows of desks all facing one direction in a traditional lecture hall to eight- to ten-person tables in a SCALE-UP classroom will have a significant effect on the stress-related endocrine responses of students.

In educational spatial design studies, the majority of which focus on primary and secondary education, freedom of movement has been shown to have a significant impact on performance (Tanner, 2000). It may then be assumed that the more constraints a space places on movement, as in a traditional lecture hall, where students may find it difficult to get in and out of crowded, narrow rows, the less conducive that space is to comfort. It has also been shown that the closer to the instructor students in traditional settings sit, the more likely they are to receive higher grades, implying that seating arrangements do have a significant impact on performance (Pichierri & Guido, 2016).

Attendance has been shown to be strongly positively correlated with academic performance (Credé, Roch, & Kieszczynka, 2010; Kassarnig, Bjerre-Nielsen, Mones, Lehmann, & Lassen, 2017; Louis, Bastian, McKimmie, & Lee, 2016; Thatcher, Fridjhon, & Cockcroft, 2007). Attendance in college classes appears to be one of the best predictors of academic success, although measurement is limited to ascertaining students' physical presence without taking into account participation or attention (Credé et al., 2010). This appears to hold especially true in the health sciences, the discipline to which many of the students' studies belong (Louis et al., 2016; Yaqoob, Bhatti, & Zulqernain, 2015).

Rather than assessing cortisol levels in the blood, which can be expensive and a traumatic experience for students, we collected weekly saliva samples, which has proven to be a reliable method of assessing serum cortisol levels (Aardal & Holm, 1995; Kirschbaum &

Hellhammer, 1994). Self-reported stress levels often have little similarity to salivary cortisol levels (Hjortskov, Garde, Ørbæk, & Hansen, 2004). Because of this, students report their emotional state before and after lecture through the use of a standardized mood chart, showing four possible stress levels ranging from high stress to less stress than usual, alongside saliva samples. We will be able to track self-reported levels of stress alongside changes in hormonal responses. Stress can be a major indicator of academic performance, so measures to mitigate stress caused by controllable variables in the classroom can allow institutions to optimize student success (Aafreen, Priya, & Gayathri, 2018). In the subjects' saliva, we will examine levels of cortisol, which will help us to more accurately assess stress levels in the test subjects.

Cortisol is the main hormone associated with stress and is released upon activation of the hypothalamic-pituitary-adrenal (HPA) axis (Pierre, Schlesinger, & Androulakis, 2017). Cortisol rises under stress conditions and can negatively impact learning (Dinse, Kattenstroth, Lenz, Tegenthoff, & Wolf, 2017). This hormone has major impacts on cognitive processes such as decision making and can therefore significantly impact academic performance (Putman, Antypa, Crysovergi, & van der Does, 2009). The relationship between high cortisol levels and impaired cognition, however, may only be a short-term one, as long-term high cortisol does not appear to significantly affect cognitive performance (McLennan, Ihle, Steudte-Schmiedgen, Kirschbaum, & Kliegel, 2016). Cortisol has been linked to statistically significant increases in stress in response to academic exams (Malarkey, Pearl, Demers, Kiecolt-Glaser, & Glaser, 1995). Cortisol levels can be affected by numerous demographic variables. Research varies as to the magnitude of the impact of sex on cortisol, with some claiming no significant difference in cortisol levels before and after stressful stimuli between males and females (Schoofs, Hartman, & Wolf, 2008) while others show a significant impact of testosterone on cortisol (Maestripieri, Baran, Sapienza, & Zingales, 2010). Cortisol release can also be increased by oral contraceptives, though those containing ethinyl estradiol also increase the release of corticosteroid-binding globulin (CBG). CBG binds to cortisol and could mitigate the increase of cortisol in the bloodstream (Dettenborn, Tietze, Kirschbaum, & Stalder, 2012). Other drugs, including SSRIs, show minimal effect on measured cortisol levels (Ronaldson, Carvalho, Kostich, Lazzarino, Urbanova, & Steptoe, 2018). Cortisol levels have also been shown to be elevated during the winter months due to effects of the light-dark cycle on the suprachiasmatic nucleus (Pierre et al., 2017). Samples were taken for this preliminary study only during winter months. Because of these measurable effects, students were screened based on factors such as regular medications, sex, and extracurricular responsibilities. Those taking corticosteroids (such as prednisolone and dexamethasone), which interfere with detection of cortisol in assays, and certain blood pressure medications (such as doxazosin and propranolol), which interfere with salivary availability, were excluded from the study (Granger, Hibel, Fortunato, & Kapelewski, 2009).

Because stress responses have such a significant effect on academic performance, measures to reduce unnecessary stressors are integral to student success. Many external factors may have an impact on stress and have been taken into consideration when designing this study, such as the stress levels of the instructor and students' academic classification. Because lecturer stress levels can influence the stress levels of students and vice versa, the lecturer must also provide saliva samples before and after each class (Oberle & Schonert-Reichl, 2016). Fourth-year undergraduates also have shown a lessened stress response when compared to first- and second-year undergraduates (Maestripieri et al., 2010).

Methodology

We recruited students from two course sections of an introductory biology course to complete a survey concerning demographic and lifestyle information. To encourage a higher response rate, the instructor offered extra credit to each entire class section if a majority of students returned the questionnaire, regardless of completion or election to participate in the study. We asked questions targeting known demographic variables that may affect baseline levels of cortisol to control for natural or expected fluctuations in hormone levels unrelated to the course, the learning space, or the curriculum of the biology course being studied. We used responses on these questionnaires to identify matched pairs of students between the two lecture sections. We based matching on sex, age, marital status, credit hours, work/life balance, and medications taken. Subjects who were considered outliers in this study, such as those taking medications affecting baseline neurotransmitter levels, those with notably high regular alcohol or caffeine consumption, and those outside of the 18-29 age bracket were not included in the study, as they could not be matched to another student in the other course section. Those chosen (n=36) included eight male students and 28 female students. Eighteen of these students attended the Monday/Wednesday 11 a.m. section of the course in a traditional lecture hall classroom and the eighteen they are matched with attended to Tuesday/Thursday 11 a.m. section in a SCALE-UP classroom. Samples were taken on Tuesday for the TR section and on Wednesday for the MW section in order to ensure that the course material covered by the instructor that week was the same for each section. Students were instructed not to eat or drink anything but water in the 30 minutes prior to giving a saliva sample so measured cortisol levels were not affected by caffeine or other substances.

We collected samples using Sarstedt Salivette® saliva collection devices, which are known to have a cortisol recovery rate close to 100% with correct use and storage. We provided students with the Salivette® tubes for saliva collection in the ten minutes before and the ten minutes directly after the lecture was given. As they gave samples, participants were asked to provide a sticker denoting their stress level at the same time. These self-reported stress stickers had four possible options: less stress than usual (green), an average level of stress (blue), a slight increase in stress (yellow), or an unusually large amount of stress (red). We attached the selected self-reported stress sticker to the associated saliva sample tube. Once all samples were collected during each sample period, we extracted the saliva samples by centrifugation of cotton swabs and stored at -80ºC until analysis.

We gathered data on student attendance for each of the full course sections (n=98) using Top Hat technology which allows students to answer in-class questions and mark themselves present only when their physical location in the classroom is verified by GPS data collected by the mobile application. We also gathered data on academic performance by documenting exam grades (with two exams given in this study period).

We analyzed self-reported stress levels between sections using a paired t-test in which we compared the average pre-lecture and post-lecture stress levels, represented on a numeric scale from 1 (most stressed) to 4 (least stressed). We then used paired t-tests to identify any potential significant differences in student attendance and academic performance in each section.

We are in process of analyzing cortisol stress biomarkers using a Cayman Chemical Cortisol Enzyme-Linked Immunosorbent Assay (ELISA) kit. This is an acetylcholinesterase competitive ELISA which produces a color change denoting levels of free cortisol present in a sample. These levels will be analyzed using a paired t-test in which average pre-lecture cortisol levels are compared to average post-lecture cortisol levels in each course. We will compare hormonal values between sections and time using a two factor ANOVA. We will calculate a linear regression to determine if student reported stress states act as an effective predictor for biomarkers. We will then calculate average exam scores and average hormonal values to find the Pearson's r coefficient along with calculating the central tendencies. This correlation coefficient will determine if there is a significant relationship between performance and physiological parameters.

Results

Self-reported stress levels

On average, students in a SCALE-UP classroom did not report significant differences in stress levels before (M = 2.70, SE = 0.51) versus after (M = 2.62, SE = 0.64) lectures ($t(17)$ = 0.89, p = 0.39, r = 0.21). Likewise, students in a traditional lecture hall did not report significant differences in stress levels before (M = 2.79, SE = 0.39) versus after (M = 2.85, SE = 0.37) lectures ($t(17)$ = -0.42, p = 0.68, r = 0.10). When comparing the two learning environments, we found no significant difference between average student reported stress levels in the SCALE-UP classroom (M = 2.66, SE = 0.52) compared to the traditional lecture hall (M = 2.82, SE = 0.29), $t(17)$ = -0.78, p = 0.45, r = 0.19.

Student academic performance

We found no significant difference (t = -0.04, p = 0.97, r = 0.004) between student attendance in the SCALE-UP classroom (n = 98, M = 0.78, SE = 0.06) compared to students in the traditional lecture hall (n = 98, M = 0.78, SE = 0.05). We also found no significant difference in academic performance on exams (Exam 1: t = 1.93, p = 0.06; Exam 2: t = 1.45, p = 0.15) between students in the SCALE-UP classroom (Exam 1: n = 91, M = 65.1; Exam 2: n = 91, M = 64.77) and students in the traditional lecture hall (Exam 1: n = 94, M = 65.71; Exam 2: n = 94, M = 67.98).

Discussion

Although self-reported stress levels did not show a significant difference between course sections, it is worth noting that average self-reported stress was lower in the traditional lecture hall setting, and while students reported an average slight increase in stress from the beginning of lecture to the end in the SCALE-UP space, students in the traditional lecture hall reported a slight decrease in stress levels. It is possible that other effects, such as noise and smells due to construction in the building featuring SCALE-UP classrooms, as well as the presence of large windows in the traditional lecture hall room, could have impacted student stress, as both construction noise and lack of natural light have shown significant impact on student satisfaction with learning spaces (Castilla, Llinares, Blanco, & Brava, 2017; Zannin & Marcon 2007). Students may also have experienced a slight increase in stress in the SCALE-UP spaces due to the orientation of their seats, which forced them to face other students whom they may not know, and could have given the impression of being watched more closely by the lecturer than students might have been in the traditional lecture hall.

Academic performance on both exams was analyzed only for students who sat the exam (scores of zero given to students who did not attend were not included in statistical calculations). The positive effect of active and blended learning techniques on exam grades is well documented, but there is a paucity of data on whether different seating arrangements in tertiary education alone have any effect on these metrics (Grzybowski & Demel, 2015; López-Perez, Perez-López, & Rodriguez-Ariza, 2011). Seating arrangement has been shown to have a significant impact on exam grades and overall course performance in the traditional lecture hall, with proximity to the lecturer, projector screen, and entryway all factoring into the ideal learning zone in which exam grades and interaction with the lecturer are highest (Zoromodian et al., 2012). Studies analyzing the effects of SCALE-UP spaces have not tended to divorce the space from the active learning pedagogy, but regardless show positive impacts on academic performance which were not shown in this study (Hacisalihoglu, Stephens, Johnson, & Edington, 2018). It may then be assumed that the majority of improvement on academic success seen in SCALE-UP classrooms may be credited to the teaching techniques utilized and not to the layout of the space, as shown in previous analyses of the impact of instructional approach rather than technologies on student performance (Lasry, Charles, Whittaker, Dedic, & Rosenfield, 2013).

Attendance may be affected by multiple factors other than stress or student motivation. Such factors, such as medical and family emergencies, illness, traffic, and parking, are difficult to track and quantify and thus were ignored in this sample. All absences, whether excused or unexcused, were included in the proportion of classes missed for all students. It is likely that the attendance rates observed in each section are close to a national average college course attendance rate and are similar to attendance rates observed at other campuses (Dobkin, Gil, & Marion, 2010; Dey, 2018).

As analysis of salivary samples continues, we hope to provide a better picture of how classroom space can impact student stress and comfort. As this study moves forward, we anticipate finding out students' endocrine responses to space.

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