Behavioral and physiological correlated of stress related to examination performance in chemistry college students

M. Bardi\textsuperscript{1*}, T. Koone\textsuperscript{1}; S. Mewaldt\textsuperscript{1}; K. O'Connor\textsuperscript{2};

\textsuperscript{1} Dept of Psychology, Marshall University, Huntington WV 25755
\textsuperscript{2} Dept of Chemistry, Marshall University, Huntington WV 25755

\textbf{*Corresponding Author:}

Massimo Bardi, Ph.D.
Marshall University, Huntington, WV 25575
Psychology Department, Harris Hall 212
Telephone: (304) 696-2775; Fax: (304) 696-2784
Email Address: bardi@marshall.edu
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Abstract - The present study was designed to assess the physiological and behavioral correlates of academic stress during a college course in organic chemistry in the United States. Participants (45 females, 46 males, mean age = 19.88), were screened for their basal hypothalamic–pituitary–adrenocortical (HPA) activity using saliva samples collected at the beginning of the course and after each major test. Displacement activities were observed during each test by videotaping students' behavior when they were taking the tests. These variables were then used as predictors of the students' achievement as measured by their grade point average (GPA), American College Testing (ACT), and their final grade in the class. Ninety-six students, enrolled in Organic Chemistry I at Marshall University during the summer 2009, were recruited for this study. It was found that individual differences in the physiological stress responses are a factor in predicting the students' ability to pass a challenging class. A logistic model built on GPA, displacement activities during stress, and hormonal concentrations was able to classify correctly almost 90% of the students passing the class. The same model was not nearly as successful in determining the possible factors behind failing the class, since the classification success was just 52%, a figure close to chance. We believe that a clear set of characteristics related to the students' ability and resilience to psychological stress are necessary to succeed in a challenging class, the reason behind dropping or failing a class could be less defined. These data indicated that investigating the physiological and behavioral propensities associated with psychological stress can help us better understand the individual’s coping responses to a long-term, challenging situation.

Key-words: Organic Chemistry; Psychological Stress; Cortisol; DHEA; Academic Performance
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Introduction

The transition from high school to college represents a significant challenge for many young people (Giddan 1987; Brissette et al. 2002). Often it is likely to be the single most dramatic change in their adult lives. Unfortunately, many students are not able to adapt to this transition. In the United States of America, only 40% of entering freshmen at public colleges and universities graduate. While the numbers are better at private institutions, still only 57% of entering freshmen graduate (Raley 2007). Psychological stress for college students is often associated with the pressure for academic success, which probably reaches its peak during tests (Robotham and Julian 2006; Izawa et al. 2008). Psychological stressors may be an important factor in affecting academic success, however they usually do not produce extreme physiological responses. In fact, they are often viewed as the norm, a necessary consequence of our fast-paced, high-demanding societies (Dowbiggin 2009; Amir et al. 2010). These factors may explain why there are few studies attempting to assess the impact of psychological stress on academic success (Wang and Yeh 2005; Wemm et al. 2010). Most studies concerned with predicting success in college focus on students' ability and students' prior academic performance (Willingham et al. 1990; Schmitt et al. 2009). When other individual characteristics have been examined, researchers have focused on cognitive traits such as perceived self-efficacy and attribution for success and failure (Liu, 2003; Zinta 2006; Li and Young 2009), dysfunctional attitudes and irrational beliefs (Zeidner 1998; Wong 2008), or self-reported coping styles (Petrie and Helmcamp 1998; Shewchuk et al. 1999; Rao et al. 2000).

Chronic stress can have deleterious effects on an individual's ability to function (McEwen, 2003, 2005; Le Moal 2007). For students it is likely to interfere with academic performance. Resilient individuals can efficiently adapt in a challenging environment, thereby
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reducing the negative consequences of chronic stress (Feder et al. 2009). Thus, it is expected that resilient students can minimize stress during examinations and achieve better results.

Recent evidence has shown that resilience correlates with reduced hypothalamic–pituitary–adrenocortical (HPA) axis activity during stress (Chida and Hamer 2008), but cortisol alone is not an adequate measure of chronic stress. Indeed, individuals who generally experience little anxiety should benefit from test conditions that increase their HPA activity, while individuals who are chronically anxious should possibly perform better under lower HPA activity. According to the Yerkes-Dodson’s law (1908), the relationship between arousal level and performance can be plotted as an inverted U; effectiveness increases as arousal increases – up to some optimal point – after which further increases in arousal produce a decrement in performance (Sonstroem 1984). When physiological arousal exceeds the optimal point, our body tries to minimize the stress by releasing chemicals that are thought to counterbalance the negative effects of cortisol (Charney 2004). Dehydroepiandrosterone (DHEA) is among these chemicals. Studies using saliva samples have shown that DHEA is secreted in response to psychosocial stressors such as public speaking (Shirtcliff et al. 2007; Izawa et al. 2008). DHEA has also been shown to be released in parallel with cortisol during physical stress (Charney 2004; Izawa et al. 2008) to protect the body against the negative effects of prolonged exposure to glucocorticoids (Morgan et al. 2004). In our laboratory, an experiment designed to simulate academic stressors found that individuals who showed less nervous behavior during an impossible task had the lowest probability of dropping or failing classes, and they also had higher ratios of DHEA versus cortisol concentrations (Wemm et al. 2010).

Little attention has been given to behavioral changes that are elicited by psychological stressors during a challenging situation (Troisi 2002; Blöte et al., 2009). Displacement activities
are behavioral patterns occurring in situations in which one would not expect to observe them, such as when students fidget with a pen or adjust their hair during a test (McFarland 1966). A vast literature on both human and nonhuman primates has consistently found that displacement activities can provide a good indicator of psychosocial stress (Bardi et al 2003; Leavens et al. 2004; Kalueff et al. 2010). Other studies have shown that children and young adolescents with social anxiety and performance deficits are more likely to show overt nervous behavior (Spence et al., 1999; Alfano et al., 2006; Blöte et al., 2009).

The aim of the present study was to assess the physiological and behavioral correlates of academic stress during a college course in organic chemistry in the United States. Organic Chemistry is traditionally perceived as a challenging course in which the success rate can be as low as 30-40% (Legg et al. 2001). Because the course is a prerequisite for medical school, a large percentage of the students taking the class in the United States are pre-med students. At the beginning of the course and after each major test, participants were screened for their basal HPA activity (cortisol and DHEA) using saliva samples. Displacement activities were observed during each test by videotaping students when they were taking the tests. These variables were then used as predictors of the students’ achievement as measured by their college grade point average (GPA), American College Testing (ACT) scores, and their final grade in the class. Specifically, our main hypothesis was that students with higher concentrations of DHEA activity in comparison to cortisol activity would be more likely to complete the class with higher final grades. We also predicted that students showing more displacement activities during the tests, an indication of overt anxiety, would earn lower grades and passing rates.

2. Methods

2.1 Participants and Academic Performance
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Ninety-six students (mean age = 19.88 ± 1.36 SD), enrolled in Organic Chemistry I at Marshall University during the summer 2009, were recruited for this study. This study was approved by the Office of Research Integrity (Marshall University Institutional Review Board # 2 – Social/Behavioral – 5/222009 IRBNet ID# 120570-2), and was therefore performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All participants gave their informed consent prior to their inclusion in the study. Classes met once a week on Tuesdays, between 17:00 and 21:00 hours. Examinations were given between 17:00 and 18:30 hours. American College Testing (ACT) composite scores, graduate point average (GPA) at the time of the participation in the study, and the number of college courses dropped or failed (D/F index) in the previous semesters were collected for all the participants to assess their overall academic performance.

2.1 Physiological Assessments

Saliva samples were collected six times for the cortisol and DHEA assessment: at the beginning of the course and after each test, including the final examination. Samples were collected in the classroom in the presence of a trained research assistant between 17:30 and 19:00 hours. Due to some students missing a test, or loss of samples during the extraction and assays, we did not have samples for all individual for each test. On average (we needed at least two samples) we were able to obtain data from 80 individuals out of 96 students for both cortisol and DHEA. Attrition analysis for the missing individuals is provided in the results. Participants were asked to refrain from eating, drinking, or brushing their teeth before experimental sessions, and to rinse their mouth with water just before sample collection. Smoking was prohibited in classroom buildings so participants did not smoke during data collection. Participants self-reported awakening time was collected to normalize the individual secretion patterns. Because
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the collection time was early evening, cortisol awakening response was not an issue. Participants were asked to expectorate through a plastic straw into a collection tube. Immediately after the collection, samples were stored at -70°C until assayed. Prior to the assays, saliva samples were shaken vigorously in a mixer for approximately 30 s. Next, the tube was centrifuged for 15 min at 3000 rpm. Using a transfer pipette, the supernatant was transferred to a 13 x 100 mm glass test tube. The final steps of the assay procedure were performed according to the instructions of the manufacturer of the assay kit (Salimetrics, Ann Arbor, MI). Sample readings were completed using an automated micro-plate reader (BioTek, Highland park, VT, model # EPOCH) and the Gen5 software (BioTek, Highland park, VT, version 1.09). Readings were assessed at a wavelength of 450 nm, with corrections at 490 nm.

The cross-reactivity of the DHEA kit was 100% with DHEA, 30% with DHEA sulfate, and considered negligible for other steroids (under 1% of androstenedione, androsterone, and so forth). The cross-reactivity of the cortisol kit was 100% with cortisol and prednisolone (122%), 27.68% with corticosterone, 4% with 11-deoxycortisol, and negligible for other steroids (under 1%). The assayed standards generated a line with slopes ranging from 0.87 to 1.04 and a correlation coefficient of 0.94. Intra-assay precision (%CV) of the DHEA kit was 7.14%. Inter-assay precision (%CV) was 9.67%. Sensitivity of the kit was 2.90 pg/mL. Intra-assay precision (%CV) of the cortisol kit was 11.91%. Inter-assay precision (%CV) was 12.24%. Sensitivity of the kit was 56.80 pg/mL.

2.3 Behavioral Assessment

Behavioral responses to the tests were videotaped for all participants. Each student was observed for about 5 min per test (25 min in total). Videotapes consisted of an overall shot of the entire classroom from different angles. Considering that the classroom was quite crowded, it
was impossible to have an unobstructed view of all participants at all times. Coupled with the fact that not all students took all examinations, we were able to collect some behavioral information on 83 out of 96 participants (an average of 62 out of 96 per test). Attrition analysis for the missing individuals is provided in the results. Using standard ethological methods (Lehner, 1979), videotapes of participants' behavior during the tests were scored and analyzed for both duration (sec / min) and frequency (events / min) for the following displacement activities: playing with the pen or paper, massaging a part of the body, stroking the hair, visible expression of anger or disappointment (such as shaking head or raising eyebrow), self-touching (prolonged contact of the hands with other parts of the body), and rejection of the test (momentary or definitive refusal to continue the test, such as taking a break or leaving the room). Videotapes were coded using a double-blind procedure, the observer being unaware of the identity or current grade of the students.

2.4 Procedure

During the first day of the course, we explained that participation in this study was voluntary and that the main goal of the study was to determine factors related to success in a challenging class such as organic chemistry. Next the procedure and the informed consent were explained in detail, and students who decided to participate read and signed the consent form. Preliminary saliva samples were taken immediately after participants signed the informed consent. In addition, a questionnaire was given on the first day of class to gather information about participants' demographic characteristics and attitude toward the class. The questionnaire was composed of standard questions using a 4-point Likert scale, ranging from 1 (not at all) to 4 (very). Examples of questions included are: “How challenging do you expect this course will be?”, and “How anxious are you in regard to this course?” After that, videotapes and saliva
samples were taken each time a test was given (test dates were June 9, 20, July 21, August 4, and the final examination was given on August 11, 2009). All tests began at 17:00 hours, and students were videotaped while attempting the test. Saliva samples were collected individually as soon as the student completed the test. Individual collection times ranged from 17:30 to 18:30 hours. Samples were stored at -70°C within 30 min of their collection.

2.5 Statistical Analysis

For descriptive purposes, we used univariate analyses. All statistical analyses were conducted using the SPSS computer program (SPSS 16.0, Chicago, IL). All measures are expressed as mean ± SD. Mixed repeated-measure ANOVAs were used to assess variations in average scores, physiological response, and behavioral response during the semester. Factors were gender (2) and passing or dropping/failing (2); the repeated measure was test times (5). Correlation among variables was assessed using Pearson’s product-moment coefficients. Stepwise regression was used to examine associations between average examination scores earned in the class and previous measures of academic success (ACT, GPA, D/F index), physiological activation, and behavioral responses to the tests. Binary logit regression was then used to predict the probability a student would pass or drop/fail the organic chemistry class on the bases of the best predictors of the average scores. Prior to analysis, normal distributions for all dependent variables were established using the Kolmogorov-Smirnov test (p > 0.1). When necessary, corrections for inequality of variance or lack of sphericity were applied.

3. Results

3.1 Class Characteristics and Academic Performance

Forty-five participants (49%) were female, 46 (51%) were male. The mean ages of the female and male participants were not significantly different (mean age: 19.88 ± 1.38 SD; t89
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=0.97, ns). In addition, there were no significant differences between genders in all measures (GPA, ACT, D/F index, anxiety toward the class, behavioral and physiological responses during the tests) except for the final grade earned in the current class, which was significantly higher in males (males: 70 ± 14 SD; females: 59 ± 14 SD; t_{95}=3.74, p<0.001).

The majority of participants (67%) declared they were majoring in biology, 17% declared a major in chemistry and the remaining 16% were majoring in other disciplines. On the first day most students (91%) expected organic chemistry to be challenging. Fifty-nine percent of the students declared they were significantly anxious at the beginning of the course (answer 4 in the 4-point Likert scale). Only 10% declared very little or no anxiety at the beginning of the course (answers 1 and 2). The remaining 31% declared to be moderately anxious (answer 3). Three percent took the course as an elective. For all the other students this course was a requirement for either their major or their minor.

GPA scores on a four-point scale ranged from a minimum of 2.4 to a maximum of 4.0; the average GPA score for the participants was 3.34 ± 0.50 SD. Prior to this class, participants had dropped an average of 2.52 ± 0.56 SD classes (maximum number = 35) and had failed an average of 0.55 ± 0.14 SD classes (maximum number = 6). We computed a composite index (D/F index = number of classes dropped + number of classes failed) that returned an average score of 3.07 ± 0.65 SD. ACT composite scores ranged from a minimum of 17 to a maximum of 34, with an average value of 25.20 ± 0.38 SD.

At the end of the course, the average grade for students was a C. In total, 17 people (18%) earned an A, 16 (16%) earned a B, 14 (15%) earned a C, 16 (16%) a D or less, and the remaining 33 (35%) dropped the class. Table 1 provides information on how many participants were sampled at each test time. As shown in the table, dropping the class was a gradual event
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until the very end of the class. Attrition analysis of the students who eventually dropped the class revealed that their mean ACT score was 24.73 ± 3.31 SD, their GPA score was 3.23 ± 0.38 SD, their D/F index was 3.94 ± 6.99, and their mean score in the class until they decide to drop it was 53 ± 10 SD. Average test scores were computed for students dropping the class as well, as long as at least 2 testes were completed.

Obviously, there was a significant difference in the average test scores earned between students who passed and students who dropped or failed the course (F1,73=28.5, p<0.001); indeed, whereas the two groups had similar scores on the first two tests, scores during the last three tests, which includes the final, decreased dramatically in the students who did not pass the course (Fig. 1). There was no main effect or interaction involving gender in the average scores earned on different tests (F1,73=1.40, ns).

The test average earned in the class was highly correlated with previous GPA scores (r = 0.49, p<0.001) and moderately correlated with ACT scores (r = 0.26, p = 0.024). It was also negatively correlated with the D/F index (r = −0.24, p=0.022). There were no significant differences in these correlations by gender.

3.2 Physiological Concentrations

Cortisol concentrations did not change significantly during the semester (cortisol: F5,90=0.64, ns). Cortisol concentrations did not differ significantly between students who passed the class and students who dropped or failed the course (F1,77=1.46, p=0.24), and there was no interaction in cortisol concentrations between gender and passing the class as well (F1,77=0.69, p=0.61).

DHEA concentrations did not change significantly during the semester (DHEA: F5,90=1.51, ns). DHEA concentrations were significantly higher in students who passed the class
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in comparison to students who dropped or failed the course (F1,77=2.94, p<0.01) (Fig. 2). Again, there were no gender effects.

The average ratio of DHEA to cortisol was also significantly greater in students who passed the course in comparison to students who dropped or failed the course (F1,77=2.17, p=0.04). Test score average was positively correlated with DHEA concentrations (r = 0.40, p<0.001) (Fig. 3), and negatively correlated with the cortisol/DHEA ratio (r = −0.26, p=0.020), but not with cortisol concentrations (r = 0.16, p=0.15). When only individuals who passed the class were considered, the average scores were still positively correlated with DHEA concentrations (r = 0.29, p=0.040), but the correlation with the cortisol/DHEA ratio was no longer significant (r = −0.13, p=0.35).

3.3 Behavioral Responses

The average frequency of displacement activities increased steadily from the first test to the final test: from an average of about 5 occurrences / minute during the first test, displacement activities rose to almost 8 occurrences / minute during the final (F4,80=6.43, p<0.001). Moreover, the average number of displacement activities was significantly higher in students who dropped or failed the class in comparison to students who passes the course (7.33/min versus 5.24.min) (F1,81=13.04, p<0.001) (Fig. 4).

Displacement activities were inversely correlated with the average grade earned in this class (r = −0.35, p=0.001) (Fig 5), and positively correlated with the D/F index (r = 0.43, p<0.001), but did not correlate with any of the physiological measures (all p-values>0.35). Focusing on the students who passed the class, the same relationships were also significant.

3.4 Regression Models
A stepwise regression model was performed on the final scores earned in the class. Previous academic performances (D/F index, ACT, and GPA scores), behavioral responses, and physiological responses during the semester were all included in the model. In Step 1 of the model, GPA scores was included ($R^2=0.296; F_{1,67}=28.22, p<0.001$) (Table 2). In Step 2 of the model, average DHEA concentrations were entered, and the percentage of variance explained improved about 10% ($R^2=0.395; F_{2,66}=21.51, p<0.001$) (Table 2). In the final step of the model, displacement activities were included and increased the percentage of variance explained by an additional 4% ($R^2=0.435; F_{3,65}=16.61, p<0.001$) (Table 2). These three predictors were able to explain a considerable proportion of the final score (above 40%).

A binary logistic regression was then used to determine the characteristics of the students who passed the class versus those who dropped or failed the course. We included in the model the three variables that returned the best model of the final grade (GPA, DHEA, displacement activities) and we calculated the percentage of students we were able to classify correctly in the two categories (pass/drop-fail). The best model ($-2\log \text{Likelihood}= 78.71$), was able to correctly classify 87% of the students who passed the class but just 52% of the people who dropped or failed the class.

4. Discussion

The main novel finding of the current study is that individual differences in physiological propensities to long-term stress are a factor in predicting students' ability to pass a challenging class such as organic chemistry. Although our study did not examine the causal relationship between the student responses to stress and final grades, previous studies have indicated a causal relationship between physiological and behavioral resilience (Bernardi et al. 2005). The students in the present study were monitored throughout the summer term, and we found that the students...
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earning a passing grade were the ones with better GPA scores, with the ability to remain calm in the face of psychological stress (as measured by the lower rate of displacement activities observed during the tests), and who were characterized by an overall higher level of DHEA, a hormone known to minimize the negative effect of HPA activity during stress (Charney 2004; Morgan et al. 2004; Feder et al. 2009). A logistic model built on these three individual characteristics (GPA, displacement activities during stress, and DHEA concentrations) was able to classify correctly almost 90% of the students passing the class. Studies in both humans and animal models suggested that increases in stress can be associated with improvement in working memory and emotional responses (Lambert et al., 2006; Lewis et al., 2008; Hawley et al., 2010). Our findings indicate that such an increase can confer a significant advantage when coupled with the secretion of higher concentrations of chemicals able to counteract the negative effects of stress.

The same logistic model was not nearly as successful in determining the possible factors behind failing the class, since the classification success was just 52%, a figure close to a randomized choice. We can only speculate on the reason for such an important difference. We believe that whereas a clear set of characteristics related to the students' ability and resilience to psychological stress are necessary to succeed in a challenging class, the reason behind dropping or failing a class could be less defined. A host of factors that are beyond the student's academic, cognitive, and physiological characteristics, including significant negative life events affecting the student while taking the course, could explain this larger variability (Shulman et al. 2009). Students with a diagnosis of internet addiction, for example, failed a significantly higher number of college tests (Mei et al. 2008). It is also well-known that adverse life events can lead to sadness, anhedonia, appetite loss, and depression, thus decreasing the ability of a student to
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 maintain demanding study times and schedules in college (Keller et al. 2007). Moreover, we were not able to collect background information such as history of smoking, drinking, illness, medication, body weight, and exercising, all factors that clearly could play a major role in both stress responses and academic success. This is a limitation that needs to be addressed in further studies.

Our results indicated that both DHEA concentrations and frequency of displacement activities did not change significantly throughout the semester. This is a very interesting result, since one might hypothesize that the students who had been successful would have higher self appraisals of efficacy because of this success, and could have changed their physiological and behavioral responses as a result. Several studies have reported cognitive behavioral characteristics of patients who, as a result of improved self appraisals in therapy, improved their physiological response (VanderArk and Ely 1992; Kao 2006; Markopoulou et al. 2009). Our study, on the other hand, clearly indicated that physiological and behavioral responses are actually predictive of the probability of success in a challenging class. This is not the same as arguing that students cannot be helped by improving their physiological and behavioral responses to a psychological stressor such as academic pressure and test anxiety. Considering the number of studies pointing out how helpful cognitive behavioral therapy can be in many cases (Nadeem and Jensen 2009; Ritter et al. 2010), we believe that studies focusing on the relationship between students’ neuroendocrine characteristics and participation in behavioral therapy sessions would be helpful.

Considering that we did not collect data on the subjective level of anxiety experienced by the students during the semester, and that certainly the DHEA / cortisol ratio cannot be used selectively as a measure of the overall physiological responses (Lambert et al., 2006; Hawley et
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al., 2010), other alternative explanations on the relationship between academic success and HPA activation cannot be ruled out. In particular, mood disorders, learning impairments, and other background life events could all interfere with both the HPA activity and academic performance.

Most studies on stress responses have concentrated on the measurement of physiological and subjective correlates of stress, leaving out detailed descriptions of the behavioral changes that are elicited by exposure to stressful situations (Drolet 2005; Salvador 2005). For example, research investigating the effect of test anxiety often relies on students' self-reports of their own psychological status as a way to gauge their anxiety level (Dubi and Schneider 2009; Attali and Powers 2010; Putwain and Daniels 2010). The Depression Anxiety Stress Scale (DASS) (Lovibond and Lovibond, 1995) has been used to assess the amount of perceived stress during the week prior to an event. The DASS has been found to be consistent and reliable in both clinical and non-clinical samples (Brown et al., 1997; Crawford and Henry, 2003). Our findings indicate that analysis of displacement activities could be an effective complement of self-report questionnaires. The analysis of behavioral patterns collectively defined as displacement activities that consist mostly of movements focused on one's own body, on the other hand, offers an objective and reliable indication of the internal status of a subject (Maestripieri et al. 1992; Castle et al., 1999). These motor patterns are consistently associated with the stress response (Virgin and Sapolsky 1999; Watson et al. 1999), are regulated by the same brain areas that are responsible for activating the physiological stress response (Dunn and File 1987; Kalueff et al. 2010), and are very often performed at an unconscious level (Freedman and Hoffman 1967; Troisi 1999), and are also consistent with an evolutionary, phylogenetic basis (Aureli and Smucny 2000). Moreover, displacement activities are easy to collect and quantify after a moderate training of the observer (Hinde 1982), and even as short as a 5-minute long task could
reveal invaluable information about the inherent behavioral choices applied in more complex activities, such as the decision of whether or not to drop classes (Wemm et al. 2010). In evolutionary terms, it makes sense. Most of our decisions and behavioral reactions are based on snap judgments (Fazio and Olson 2003; Bar and Neta 2006). This is essential for our survival. Assessment of potential threats, as demonstrated by the stress response, must be fast (Sapolsky 2003). A few seconds could be the difference between a decision that might lead to pain and suffering, and an adaptive choice. Since these mechanisms assure our survival, it is evolutionarily advantageous to base our long-term decisions on mechanisms that work well in the short-term. This may be why behavioral responses to psychogenic stress could help us identify students at higher risk of dropping or failing a challenging class.

Our study also confirms that measures of the students' previous ability and academic success, as measured by ACT and GPA scores, remains at the foundation of any investigation on the factors affecting academic success. Several models combining the students' high school GPAs and scores on standardized tests such as the ACT can predict as much as 60% of the variance of the college GPA scores (Berry and Sackett 2009). In our study, we obtained similar results, indeed GPA scores were the factor with the highest load in the multiple regression analysis. However, several other studies have pointed out the utility of using quantified indicators other than GPA and standardized test scores to predict potential academic success (Grigorenko et al. 2009).

In conclusion, our results point toward the importance of collecting individual measures of behavioral and physiological propensities as predictors of academic success. Whereas socio-demographic, psychological, and developmental studies have indicated several potential avenues
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to prevent students from dropping out of school, there are no studies attempting to integrate these data with their neurobiological characteristics.

While further studies are required to disentangle several of the issues not addressed by our data, including the acute stress response of the student for each individual test, length of the examination and changes in physiological parameters for each student in particular, our preliminary data indicated that investigating the physiological and behavioral correlates of academic stress can help us better understand the individual’s responses to a long-term, challenging situation.
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Tables:
Table 1. Average scores and number of participants sampled during each test together with mean values (± SD) of different behavioral and physiological measures in students who passed the course and students who dropped or failed the course.

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
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<tbody>
<tr>
<td><strong>Total Participants</strong></td>
<td>96</td>
<td>75</td>
<td>68</td>
<td>65</td>
<td>60</td>
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<tr>
<td><strong>Passed</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Number of participants</td>
<td>47</td>
<td>47</td>
<td>47</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Displacements activities</td>
<td>4.78 ± 1.98</td>
<td>6.49 ± 2.06</td>
<td>5.18 ± 2.03</td>
<td>6.74 ± 2.33</td>
<td>7.31 ± 3.01</td>
</tr>
<tr>
<td>Cortisol concentrations (µg/mL)</td>
<td>111.0 ± 84</td>
<td>122.4 ± 56</td>
<td>103.8 ± 66</td>
<td>106.7 ± 77</td>
<td>97.2 ± 59</td>
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<td>DHEA concentrations (pg/mL)</td>
<td>89.2 ± 51</td>
<td>121.6 ± 88</td>
<td>110.8 ± 64</td>
<td>99.7 ± 65</td>
<td>130.6 ± 90</td>
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<td>Average Score</td>
<td>71 ± 12</td>
<td>81 ± 11</td>
<td>68 ± 19</td>
<td>60 ± 22</td>
<td>77 ± 19</td>
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<tr>
<td><strong>Dropped or Failed</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Number of participants</td>
<td>49</td>
<td>28</td>
<td>21</td>
<td>18</td>
<td>13</td>
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<tr>
<td>Displacements activities</td>
<td>7.43 ± 2.26</td>
<td>7.30 ± 2.49</td>
<td>8.40 ± 2.58</td>
<td>5.37 ± 4.17</td>
<td>10.0 ± 2.27</td>
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<tr>
<td>Cortisol concentrations (µg/mL)</td>
<td>128.2 ± 102</td>
<td>98.0 ± 61</td>
<td>107.6 ± 54</td>
<td>93.9 ± 59</td>
<td>87.8 ± 90</td>
</tr>
<tr>
<td>DHEA concentrations (pg/mL)</td>
<td>71.9 ± 33</td>
<td>81.2 ± 54</td>
<td>56.1 ± 29</td>
<td>87.6 ± 69</td>
<td>78.6 ± 55</td>
</tr>
<tr>
<td>Average Score</td>
<td>57 ± 10</td>
<td>65 ± 10</td>
<td>37 ± 16</td>
<td>32 ± 18</td>
<td>41 ± 16</td>
</tr>
</tbody>
</table>
Correlates of Stress in College

Table 2. Stepwise regression model predicting the average scores in the Organic Chemistry I class. In the first step of the regression GPS scores were entered in the model. In the second step, average DHEA concentrations were entered in the model. In the final step of the regression, displacement activities (DA) during the tests were entered in the model.

<table>
<thead>
<tr>
<th>Scores</th>
<th>R</th>
<th>Adjusted $R^2$</th>
<th>b</th>
<th>SE</th>
<th>β</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1 (constant)</td>
<td>0.544</td>
<td>0.286</td>
<td>3.152</td>
<td>11.682</td>
<td>0.270</td>
<td>0.788</td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td></td>
<td></td>
<td>18.224</td>
<td>3.431</td>
<td>0.544</td>
<td>5.312</td>
<td>0.000</td>
</tr>
<tr>
<td>Model 2 (constant)</td>
<td>0.628</td>
<td>0.376</td>
<td>-1.321</td>
<td>11.002</td>
<td>-0.120</td>
<td>0.905</td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td></td>
<td></td>
<td>17.047</td>
<td>3.226</td>
<td>0.509</td>
<td>5.284</td>
<td>0.000</td>
</tr>
<tr>
<td>DHEA</td>
<td></td>
<td></td>
<td>0.086</td>
<td>0.026</td>
<td>0.316</td>
<td>3.274</td>
<td>0.002</td>
</tr>
<tr>
<td>Model 3 (constant)</td>
<td>0.659</td>
<td>0.409</td>
<td>12.460</td>
<td>12.491</td>
<td>0.998</td>
<td>0.322</td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td></td>
<td></td>
<td>15.139</td>
<td>3.265</td>
<td>0.452</td>
<td>4.637</td>
<td>0.000</td>
</tr>
<tr>
<td>DHEA</td>
<td></td>
<td></td>
<td>0.082</td>
<td>0.026</td>
<td>0.304</td>
<td>3.229</td>
<td>0.002</td>
</tr>
<tr>
<td>DA</td>
<td></td>
<td></td>
<td>-1.154</td>
<td>0.538</td>
<td>-0.209</td>
<td>-2.146</td>
<td>0.036</td>
</tr>
</tbody>
</table>
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**Figure Legends:**

Figure 1: Average scores (± SEM) on all five tests (from Test #1 to Test #5) for students who passed the course (n = 47) and dropped or failed the course (n = 49). The average scores for the last three tests were all significantly different between the two groups of students, as indicated by an asterisk (*) in the figure (F1,73=28.5, p<0.001).

Figure 2: Average concentrations of cortisol (CORT) (µg/mL ± SEM) and dehydroepiandrosterone (DHEA) (pg/mL ± SEM) during the semester for students who passed the course (n = 47) and for students who dropped or failed the course (n = 49). DHEA concentrations were significantly different between the two groups of students as indicated by an asterisk (*) in the figure (F1,77=2.94, p<0.01).

Figure 3: Scatterplot of the correlation between salivary DHEA concentrations (pg / mL) and the final grade earned in the class (n = 75) (r = 0.40, p<0.001).

Figure 4: Average number of displacement activities (measured in occurrence / minute) in all tests for students who passed the course (n = 47) and for students who dropped or failed the course (n = 49) (F1,81=13.04, p<0.001).

Figure 5: Scatterplot of the correlation between frequency of displacement activities (DA) (measured in occurrence / minute) and the final grade earned in the class (n = 75) (r = −0.35, p=0.001).