The dynamic experience of taking an examination : Ever changing cortisol and expectancy for success

Graham, Matthew C., Husman, Jenefer, Pekrun, Reinhard, Villanueva, Idalis and Christensen, Darcie

The Dynamic Experience of Taking an Exam:

Ever Changing Cortisol and Expectancy for Success

Matthew C. Graham[1], Jenefer Husman[2], Reinhard Pekrun[3,4,5], Idalis Villanueva[6], and Darcie Christensen[7]

[1]*Oregon Education Science Laboratory, University of Oregon, USA*

[2]*Department of Education Studies, College of Education, University of Oregon USA*

[3]*Department of Psychology, University of Essex, England*

[4]*Institute for Positive Psychology and Education, Australian Catholic University*

[5]*Department of Psychology, University of Munich*

[6]*Department of Engineering Education, University of Florida USA*

[7]*Iron Range Engineering, University of Minnesota – Mankato USA*

Keywords: Cortisol, Exam stress, Control-Value Theory

Data available on request due to privacy/ethical restrictions. This material is based upon work supported in part by the National Science Foundation in the United States of America (NSF) No. DUE-1661100, DUE-1661117, & EEC-1653140. Any opinions, findings, and conclusions or recommendations expressed in this material do not necessarily reflect those of the National Science Foundation.

Reference: Graham, M. C., Husman, J., Pekrun, R., Villanueva, I., & Christensen, D. (2022). The dynamic experience of taking an exam: Ever changing cortisol and expectancy for success. *British Journal of Educational Psychology.* Advance online publication. https://doi.org/10.1111/bjep.12521

Abstract

Background: This study examined the relations between students' expectancies for success and a physiological component of test anxiety, salivary cortisol, during an authentic testing setting.

Aims: The aim of the study was to better understand the connection between shifts in students' control appraisals and changes in the physiological component of test anxiety.

Sample: The study comprised 45 undergraduate engineering majors in the United States.

Methods: Survey data concerning students' expectancy for success and saliva samples were taken before, during, and after the practice midterm exam prior to their actual in-class exam.

Results: Students' expectancy for success declined during the exam while cortisol levels declined from the beginning to middle of the exam and began to increase again as a function of time. Although students' initial levels of expectancy for success and cortisol were not correlated, there was a negative relation between change in cortisol and change in expectancy for success.

Conclusions: Our study desmonstrates a relation between salivary cortisol, a physiological component of test axiety, and students' expectancy for success in an authentic testing context. Most students saw a decrease in cortisol during the exam, suggesting anticipatory anxiety prior to the test and a return to homestasis as the exam progressed. Some students, however, did not see a declination in cortisol, suggesting they may not have recovered from pre-exam anxiety. The negative relation between change in cortisol and expectancy for success suggests that students who had the greatest decrease in expectancy for success saw the smallest recovery in cortisol.

The Dynamic Experience of Taking an Exam: Ever Changing Cortisol and Expectancy for Success

Exams are frequent, consequential, and often emotion-filled experiences for students (Stöber & Pekrun, 2004). An especially frequently occurring emotion during exams is anxiety. Test anxiety has several components, including cognitive (worry), physiological and affective (combined called "emotionality" in the test anxiety literature), and behavioral components (von der Embse et al., 2018). Researchers have argued that measures of physiological arousal can be used to examine the physiological component of test anxiety and allow insights that are not possible utilizing self-report measures of emotions (Roos et al., 2020). In this study, we use control-value theory (CVT, Pekrun 2006, 2018, 2021) as a theoretical framework for studying the physiological component of test anxiety.

CVT proposes that achievement emotions are dynamic, multi-component processes that include cognitive, physiological, affective, and behavioral components. Test anxiety, one of several major negative emotions considered in CVT, is theorized to be negatively related to students' control appraisals such as their expectancies for success (Pekrun, 2006). However, the relations between control appraisals and achievement emotions, in the context of exams, have typically relied on self-report of students' emotions before and after the exam (e.g., Harley et al., 2021; Roick & Ringeisen, 2017) or self-report of students' trait emotions (von der Embse et al., 2018). CVT posits that emotions shift as students' appraisals change; however, examinations of in-the-moment relations between control appraisals and emotions in exam contexts are less common (Roick & Ringeisen, 2017). This may be due, in part, to the methodological challenges of asking students to report on the physiological component of anxiety during a cognitively demanding task (Putwain, 2007).

In this study, we use an objective measure of physiological arousal, cortisol, to explore the proposed relation between ongoing cognitive appraisals and the physiological component of test anxiety. Cortisol has been used to measure students' physiological arousal response to performance tasks in both laboratory (e.g., Dickerson & Kemney, 2004) and real-world exam environments (e.g., Ringeisen et al., 2019). Understanding the relation between control appraisals and changes in cortisol is important as reoccurring momentary rises in cortisol have a negative impact on working memory (Barsegyan et al., 2010) and adverse health effects (Juster et al., 2010). Understanding the connection between control appraisals and students' cortisol may assist in developing interventions to reduce students' frequent experience of test anxiety.

Control Appraisals and Emotion

CVT proposes that control appraisals, including self-beliefs about competence, self-efficacy expectations, and expectancies for success, influence students' achievement emotions. As students progress through a performance activity, their expectancies for success may change due to their ongoing interactions with the environment. Students' emotional experiences change as they begin, engage in, and reflect on a task, and these changes are informed by their expectancies for success (Pekrun, 2006). As a result, to understand the change of students' emotional state across the task, it is important to consider its relation with expectancy. Researchers using expectancy-value theory (EVT, e.g., Eccles & Wigfield, 2002, 2020) have theorized and demonstrated the importance of expectancies for meaningful academic outcomes. However, EVT emphasizes the importance of students' motivational (rather than emotional) experiences during academic performance tasks (Kiuru et al., 2020).

Research on the relations between dynamic expectancies for success and achievement emotions such as anxiety (Goetz et al., 2007) has been constrained by limitations inherent to self-

report methodologies, including subjectivity of appraisals of emotional states, presentation biases, and the emphasis of self-report measures on cognitive and affective components of emotions rather than physiological components (Linnenbrink-Garcia et al., 2016; Pekrun, 2006; Szafranski et al., 2012). Furthermore, using self-report during exams is problematic because exams create a high cognitive load, making self-reflection about one's emotional state difficult (see Roos et al., 2020, for a review). Objective measures of the physiological components of achievement emotions address this concern. Although relations between biological measures and self-reports of emotions may be modest (e.g., Joseph et al., 2021), these measures can provide insight into key components of students' emotional stress responses. Based on the multi-component view of emotion described above, we use change in salivary cortisol as an indicator of the physiological component of test anxiety in our study. Using this measure, we test the hypothesis that students' ongoing expectancies for success are related to their physiological response during the exam.

Emotional Stress and Hypothalamic-Pituitary-Adrenal Axis Activation

Test anxiety is an emotional, physiologically activating response to the threat that students experience in exams. The physiological component of this stress response includes activation of the hypothalamic-pituitary-adrenal (HPA) axis. Activation of the HPA axis during periods of acute threat results in a precipitous excretion of cortisol as the body mobilizes energy stores to aid in response to the perceived threat (Tilbrook, 2007), supporting the "flight-or-fight" response (Kemeny & Shestyuk, 2008). Cortisol passively diffuses into saliva proportional to serum-free cortisol, making salivary cortisol an excellent measure of the physiological component of acute stress responses. However, not all stressful settings are likely to produce an HPA-axis response and result in a significant increase in cortisol, as shown both in laboratory

research and outside of the laboratory (Schlotz, 2019). The relation between stress and cortisol has been extensively studied in laboratory settings, utilizing stimuli designed to create stress (e.g., the Trier Social Stress Test; Labuschagne et al., 2019), and in educational settings in a few studies (Adams, et al., 2011; Tomczyk & Hoferichter, 2021). It was found that uncertainty and social-evaluative tasks that trigger anxiety are the most likely to increase cortisol levels (Dickerson & Kemeny, 2004). Exams are a prime example for this type of situation, as they involve social evaluation and uncertainty about the outcome.

The expected pattern for a cortisol response to a performance task is an initial rise in cortisol just before the task and a decline following the task (Dickerson & Kemeny, 2004; Sanz & Villamarín, 2001; Schlotz, 2019; Verschoor & Markus, 2011). In the context of a long exam, initial activation of the HPA axis at the start of the exam and return to baseline, described as cortisol recovery, is expected (Spangler et al., 2002). The absence of a return to baseline suggests repeated triggering of the HPA axis and is an indicator of a maladaptive physiological arousal (Juster et al., 2010). An optimal design for capturing maladaptive lack of recovery requires the collection of several saliva samples per participant, including two samples before the performance task and four post-task samples (Granger et al., 2012).

Research on control appraisals and adaptive/maladaptive physiological arousal have frequently examined the relation between self-efficacy and physiological arousal. Control-value theory and social-cognitive theory both propose that high self-efficacy (a control appraisal) should have a protective effect, blunting the impact of the performance experience on negative emotions and increasing cortisol (Pekrun, 2006; Schönfeld et al., 2017). However, researchers have not found a consistent relation between coping self-efficacy or academic self-efficacy and physiological arousal (cortisol response) in clinical and exam settings (Schönfeld et al., 2017;

Ringeisen et al., 2019). Rather than examining general coping or academic self-efficacy, in this study we examine the relation between students' momentary, changing expectancies for success and their salivary cortisol, as an indicator of the physiological component of test anxiety, in the context of an exam.

Aim of Study

Although cortisol is a well-established indicator of physiological arousal (Dickerson & Kemeny, 2004; Verschoor & Markus, 2011; Sanz & Villamarín, 2001; Schlotz, 2019), it has been underutilized in the context of authentic academic performance tasks (Ringeisen et al., 2019). Based on control-value theory (Pekrun, 2006, 2018, 2021), we argue that measuring changes in salivary cortisol during and after an exam allows us to better understand the connection between shifts in students' expectancies for success and changes in the physiological component of anxiety during the exam. Specifically, we answer the following questions:

RQ1: Does student physiological arousal change over the course of an exam? We hypothesize that students' salivary cortisol will be higher at the start of an exam than at the end.

RQ2: Is there a relation between students' initial levels and change in expectancy for success and the initial level and change in salivary cortisol? We hypothesize that there will be a negative relation between the initial level of expectancy for success and the initial salivary cortisol level. We also hypothesize a negative relationship between change in expectancy for success and change in cortisol.

Method

Participants

Participants were 45 undergraduate students recruited using in-person announcements and an email sign-up link from an engineering statics course at a research university in the

United States Mountain West in Fall Term 2018. In the U.S., statics courses are often taken in the sophomore year as the first required engineering course for engineering majors and are generally considered a challenging course (Suresh, 2006). The statics course had three midterm exams and a final exam; students volunteered to participate before the first or second midterm exam. As part of the course students were required to take a practice midterm exam to prepare for their actual midterm. Two weeks before the exam a representative of our research team went to the course to recruit students to take their practice midterm in our testing center and participate in our research. Participants received 2.5% extra credit and a $5 gift card for participating in the study. They were provided feedback on their performance after the end of the study.

A pre-exam survey included questions about students' health, medication, tobacco use, and pregnancy. Of the initial 48 individuals who agreed to participate, three were identified as either having a medical condition or using prescription medication known to potentially influence cortisol concentrations (Foley & Kirschbaum, 2010). These participants were excluded from the study, resulting in a final sample size of 45 students. No students reported tobacco use or pregnancy. Age ranged from 18 to 32 years (mean = 22.00 years, *SD* = 2.90). Thirty-four students identified as male, 11 identified as female. Using the U.S. Federal guidelines for reporting race and ethnicity (e.g., Office of Management and Budget, 1997), 42 identified as White non-Hispanic, and three indicated another racial and/or ethnic identity. All participants indicated they were engineering majors. The mean self-reported cumulative university GPA was 3.54 (*SD* = 0.38).

Procedures

Following IRB-approved procedures, participants took the practice midterm exam approximately one week before the mid-term exam in a testing center designed to replicate an

authentic testing environment (Authors et al., 2019). Participants arrived in the afternoon (3:30-6:30 pm) and were allowed to take as much time as needed to complete the exam. All saliva samples were collected using practices recommended in salivary bioscience (Granger et al., 2012).

Prior to data collection, participants were asked not to consume any foods or beverages with artificial sugar or caffeine four hours beforehand, not to have a meal one hour beforehand, not to brush their teeth 45 minutes beforehand, and not to consume milk, dairy, or high-acidity foods 20 minutes beforehand. Upon arrival at the testing center, participants gave their written consent. They were given 1 oz. of water and prompted to swish the liquid around their oral cavity and swallow. Participants were then led to a workstation where they were oriented towards the salivary collection tools and provided an overview of the study procedures. The time between swishing water in their oral cavity and the first saliva sample varied but, in all cases, exceeded 10 minutes. Before the exam, participants watched a short video demonstrating the self-collection of salivary samples. Participants then provided their first saliva sample and reported their pre-exam expectancy for success. Immediately after reporting expectancy for success, they began the exam. Forty-five minutes into the exam, participants were directed to collect a second saliva sample and report their mid-exam expectancy for success. Participants were then allowed as much time as needed to complete the exam. Although all students fully engaged in the exam, some took longer than others. Total time to complete the exam varied from 54 to 210 minutes; the average time was 118.87 minutes (SD = 33.80). Immediately after the exam, but before receiving their performance scores, participants provided the third saliva sample and reported their post-exam expectancy for success. Twenty minutes after completing

the exam, participants provided the final saliva sample. We present the study timeline in Figure 1.

Measures

Expectancy for Success. Before, during, and immediately after the exam, expectancy for success was assessed using a single item rated on an 11-point scale before receiving results. Participants were asked to indicate the highest percent of items correct they expect to earn on the practice exam from 0% to 100% by 10% increments. This one-item measure is similar to previously used measures of expectancy for success which ask students about their expected grade or performance on a scale from 0 to 100 (Roick & Ringeisen, 2017; Shell & Husman, 2001, 2008). In the U.S., grades (A, B, C) are often determent by the percent of points or items correct: e.g., 90-100% = A.

Salivary Cortisol. Before, during, immediately after, and 20 minutes after the exam, participants were prompted to collect whole saliva using Salimetrics Oral Swabs (Salimetrics, State College, PA). All saliva sample vials were immediately collected from participants and stored at -20°C until being centrifuged, vortexed, and assayed following established protocols using an enzyme immunoassay with a sensitivity of .007 μg/dl and range from .007 to 1.8 μg/dl (Salimetrics, State College, PA). Inter- and intra-assay coefficients of variation, a measure of reliability, were 6.86 and 6.35, respectively, which is within the accepted range (Hanneman et al., 2011).

Statistical Analysis

We answered our research questions using Latent Growth Curve Modeling (LGM; Duncan & Duncan, 2009) with individually-varying times of observation (Mehta & West, 2000) using *MPlus v8.3* (Muthén & Muthén, 1998-2017). LGM is a statistical technique using a

structural equation modeling (SEM) framework to estimate growth trajectories, assuming that an individual's change in a factor across multiple measurement occasions is a function of an underlying predictable growth process (Preacher et al., 2008). LGM offers advantages over other approaches when analyzing repeated measures data in that it allows for the analysis of complex, multivariate models with multiple outcomes (Duncan & Duncan, 2009). Prior research has found that, even with a smaller sample size, LGM is particularly useful for modeling biomarkers due to its flexibility and ability to model complex data structures (Felt et al., 2017).

LGM with individually-varying observation times builds on the foundation of traditional LGM but treats time as a continuous rather than discrete factor. We present a path diagram of a univariate LGM with individually-varying times of observations in Figure 2. An individual's predicted value at a specific time point can be expressed as,

$$\Upsilon_i(t_x) = \xi_i(t_0) + \Theta_i(t_x - t_0) + \varepsilon_i(t_x)$$

where an observed score for person *i* at time t_x, $\Upsilon_i(t_x)$, is the sum of their initial level at time zero, $\xi_i(t_0)$; the product of rate of change, Θ_i; and elapsed time from the intercept ($t_x - t_0$); and the time-specific error, $\varepsilon_i(t_x)$ (Mehta & West, 2000).

Using time as a continuous rather than a discrete factor in our LGM allowed us to model inter-individual differences in the time students took to complete the exam, and to evaluate how expectancy for success and physiological arousal changed as a function of time. However, modeling individually-varying times of observations requires the use of numerical integration and definitional variables outside the variance-covariance matrix of observed variables typically used to derive parameter estimates in SEM. As a result, traditional measures of overall model fit (e.g., comparative fit index, Tucker-Lewis index; Hu & Bentler, 1999) cannot be obtained. Therefore, to evaluate the overall fit, we tested a series of nested models with an increasing

number of latent growth parameters (i.e., intercept-only, linear, and quadratic) and compared model fit using the likelihood ratio test statistic (LRTS; e.g., Lewis et al., 2010),

$$LRTS = 2(\log L_B - \log L_A)$$

where $\log L_{.B.}$ and $\log L_{.A.}$ are the log-likelihoods for models B and A, and model A is nested in model B. We evaluated the statistical significance of the LRTS assuming a χ^2 distribution with the difference in the numbers of parameters as the degrees of freedom. Additionally, we compared the Akaike Information Criterion (AIC; Akaike, 1974),

$$AIC_i = -2 \log L_i + 2p_i$$

and the Bayesian Information Criterion (BIC; Schwarz, 1978),

$$BIC_i = -2 \log L_i + p_i \log n_i$$

for model i, where L_i is the likelihood, p_i is the number of parameters, and n_i is the sample size. For both AIC and BIC, smaller values suggest stronger empirical support for a model.

We used a parallel process Latent Growth Model (PP-LGM; Preacher et al., 2008) to test the relation of expectancy for success and physiological arousal. The parallel process LGM allows us to simultaneously model growth in the two different factors and evaluate the relation between initial levels and change in both factors. To test the hypothesized relation in the change in expectancy for success and physiological arousal, we allow the intercepts and slopes of both factors to covary.

Results

Preliminary Analysis

We present correlations, means, and standard deviations for all measures in Table 1. Expectancy for success decreased from 8.58 (*SD* = 1.48) prior to the exam to 7.71 (*SD* = 1.99) 45 minutes into the exam and 6.40 (*SD* = 2.28) at the end. Correlations between all three

measures of expectancy were strong, *r*s = .52 – .68, *p*s < .01. We observed a similar declination in salivary cortisol from 0.26 μg/dl (*SD* = 0.15 μg/dl) pre-exam to 0.17 μg/dl (*SD* = 0.07 μg/dl) during the exam. However, little change was observed from this mid-exam measure to 0.15 μg/dl (0.07 μg/dl) immediately after and 0.17 μg/dl (0.11 μg/dl) 20 minutes after the exam. The correlations between cortisol levels between waves were inconsistent with a significant relation between pre- and mid-exam arousal (*r* = .33, *p* = .03) and between the two post-exam measures (*r* = .42, *p* < .01). However, we observed no other significant relations (*r*s = .16 – .25, *p*s > .05).

As a sensitivity analysis, we conducted a two-way repeated measures ANOVA with both expectancy and cortisol to identify gender differences. We did not observe any significant main effect of gender on overall expectancy (F[1,43] = 0.12, p = .73), nor any interaction effect of gender and data collection wave on expectancy (F[2, 86] < 0.01, p > .99). Similarly, we did not observe any significant main effect of gender on overall cortisol (F[1,43] = 1.02, p = .32). There also was no interaction effect of gender and data collection wave on cortisol (F[2.20, 94.59] = 1.45, p = .95).

Latent Growth Curve Modeling

We present the fit statistics and parameter estimates for all models in Table 2. To answer our first research question, we compared the model fit for three specifications of the growth trajectory parameters, one with no change (intercept-only), one with linear change (linear), and one with both linear and quadratic change (quadratic). We found that the quadratic model outperformed both the intercept-only model, LRTS (*df*) =34.34 (7), *p* < .01, ΔAIC =-20.32, and the linear model, LRTS (*df*) =21.84 (4), *p* <.01, ΔAIC =-13.84. We present a plot for this best fitting quadratic growth curve model in Figure 3. In examining explained and residual variance in our manifest variables, we found the quadratic model better fit the observed data. For the best-

fitting model, participants started high in initial salivary cortisol levels, intercept cortisol ($\mu_{C[I]}$) =0.252 μg/dL, *SE* =0.021, $p < .01$. Cortisol then declined over the course of the exam, linear slope ($\mu_{C[L]}$) =-0.126 μg/dL/hour, *SE* =0.036, $p < .01$. This decrease was attenuated by a significant quadratic term, quadratic slope ($\mu_{C[Q]}$) =0.035 μg/dL/hour^2, *SE* =0.013, $p < .01$, such that participants began to experience an increase in salivary cortisol after approximately 1 hour and 45 minutes. We observed significant variance in the intercept, $\psi_{C[I]}$ =0.017, *SE* =0.005, $p < .01$, the linear slope, $\psi_{C[L]}$ =0. 040, *SE* =0.015, $p < .01$, and the quadratic slope, $\psi_{C[Q]}$ =0.004, *SE* =0.002, $p < .01$. Additionally, we observed that initial cortisol level covaried with both the linear slope, $\psi_{C[I]xC[L]}$ =-0.025, *SE* =.009, $p < .01$, and the quadratic slope, $\psi_{C[I]xC[Q]}$ =0.008, *SE* =0.003 $p < .01$. Linear and quadratic slope were also related, $\psi_{C[I]xC[Q]}$ =-0.013, *SE* =0.005, $p < .01$.

We then estimated two univariate LGMs examining change in expectancy during the exam, one with no slope (intercept-only) and one with linear change (linear), and compared the model fit. We observed a significant improvement to model fit when comparing the linear with the intercept-only model, LRTS (*df*) =45.86 (3), $p < .01$, ΔAIC =-39.87. We present the best-fitting linear plot of this growth model in Figure 4. In examining explained and residual variances in the manifest variables, the linear model better fit the observed data at every time point when compared to the intercept-only model. For the best-fitting model, participants started high in expectancy for success; intercept expectancy for success ($\mu_{E[I]}$) =8.53, *SE* =0.24, $p < .01$. Expectancy for success then declined during the exam; slope expectancy for success ($\mu_{E[L]}$) =-1.06/hour, *SE* =0.16, $p < .01$. Although we observed significant variance in the expectancy intercept, $\psi_{E[L]}$ =1.61, *SE* =0.55, $p < .01$, there was less variance in slope, $\psi_{E[I]}$ =0.22, *SE* =0.33, $p = .51$. Additionally, we did not observe a significant covariance between initial level of expectancy and change in expectancy, $\Psi_{E[I]xE[L]}$ =.35, *SE* = 0.19, $p = .42$.

To answer our second research question, we estimated a parallel process LGM examining the relation of initial level and change in expectancies and cortisol during the exam. As we had already determined the best-fitting growth trajectory for both expectancies and cortisol independently, we fit only a model assuming a linear change in expectancy and a quadratic change in cortisol. We observed no covariance between initial levels of expectancy and cortisol, $\psi_{E[I]xC[I]}$ =0.023, *SE* =0.035 *p* =.50. The initial level of expectancy was also unrelated to either linear change in cortisol, $\psi_{E[I]xC[L]}$ =-0.067, *SE* =0.057, *p* =.24, or quadratic change in cortisol, $\psi_{E[I]xC[L]}$ =0.021, *SE* =0.020, *p* =.30. Initial level of cortisol, however, positively covaried with change in expectancy, $\psi_{C[I]xE[L]}$ =0.047, *SE* =0.019, *p* =.01; individuals with higher cortisol levels were less likely to experience as great a decrease in expectancy for success during the exam. Negative linear change in cortisol inversely covaried with a negative linear change in expectancy, $\psi_{C[L]xE[L]}$ =-0.075, *SE* =0.024, *p* <.01; individuals who experienced a less negative linear change in cortisol experienced a greater decrease in expectancy for success. Individuals who experienced a greater decrease in expectancy also experienced greater quadratic change in cortisol, $\psi_{C[Q]xE[L]}$ =0.026, *SE* =0.008, *p* <.01.

Discussion

This study used changes in salivary cortisol as an indicator of the physiological component of test anxiety. We examined the relation between change in salivary cortisol and change in students' expectancy for success as proposed by CVT. In the context of a mid-term authentic practice exam, students experienced a significant decrease in salivary cortisol during the exam, echoing prior research that has found that individuals often experience spikes in cortisol in anticipation of an exam (e.g., Schoofs et al., 2008; Spangler et al., 2002). Additionally, a significant quadratic term attenuated students' declination in salivary cortisol.

Prior research on the cortisol response to performance tasks has been conducted using short tasks (e.g., 20 min; Kirschbaum et al., 1993). In the authentic exam environment we used for this study, participants were allowed to take as much time as necessary to complete the exam, with one participant taking over three hours to complete the exam. This additional time allowed some participants to experience a second wave of physiological arousal near the end of the examination, with model-predicted salivary cortisol levels again beginning to increase 1 hour and 45 minutes into the exam. This second wave of cortisol response occurred near the end of the exam for most participants. However, it is unclear if participants' physiological arousal increased due to the increased difficulty of the last several questions, the anticipation of performance feedback (i.e., receiving the results of the practice exam), a cyclical pattern in which students experience waves of stress-related HPA-axis activation separated by intervals where their bodies recover, or some other factor. Future research should be conducted to examine the function of time in relation to physiological arousal during academic exams.

We also found evidence to partially support the hypothesized negative relation between initial level and change in expectancy for success and the indicator of the physiological component of test anxiety, cortisol. CVT proposes that control appraisals such as expectancies for success will be negatively related to negative emotions such as test anxiety. In our study, however, expectancy for success and initial cortisol levels were unrelated. We did find that there was a significant relation between the change in expectancy and the change in cortisol. Students who reported a greater decrease in expectancy for success throughout the exam experienced less recovery from their pre-exam cortisol levels. The lack of relation between initial expectancies for success and cortisol is inconsistent with our expectations based on the CVT. However, our

findings confirm that initial expectancies may frame students' emotions – at least in terms of physiological arousal - throughout the exam.

The findings have implications both for CVT and for researchers who examine cortisol in the context of exams (Lacey et al., 2000, Verschoor & Markus, 2011). Researchers have questioned the proposed protective effects of self-efficacy against both acute and chronic stress-related physiological arousal (Schönfeld et al., 2017); other studies have not found relations between self-efficacy and either the initial rise in cortisol or change in cortisol during authentic oral exams (Ringeisen et al., 2019). However, self-efficacy was measured typically at the beginning of a task, and changes in outcome expectancies were not considered. The findings of our study support the proposition that control appraisals and physiological components of emotions are dynamic processes. To explore these dynamic relations proposed by CVT, research which investigates these phenomena in-situ is needed (Kiuru et al., 2020).

When thinking about possible applications of this work to practice, it is interesting that students' initial expectancy for success did not predict their level of stress at the start of the exam. Students' revisions of their expectancies after being confronted with the actual exam were related to either regulation or dysregulation of their HPA-axis. As we think about how to support students, providing them with strategies to address their stress during an exam or to support control appraisals during the exam may be of value. Additionally, these results indicate that researchers who are interested in the relation between control beliefs and biological markers need to look at changes in students' beliefs before, during, and after the exam.

There were several limitations to the present study. Our sample size was small, particularly for the complexity of the statistical models we used. Due to the structure of our data and the necessary use of individually-varying times of observation PP-LGM, we were not able to

use the recommended Bayesian Estimation technique for small sample sizes (Felt et al., 2017). Future research utilizing a larger sample size will be needed to confirm the patterns of relations observed in this study and to explore the dynamic nature of the relations between control appraisals and physiological responses. We did not capture students' cortisol awakening response, which could better contextualize students' cortisol response during the exam (e.g., Dienes et al., 2019). Future research should consider capturing morning saliva samples to provide more context for students' responses during the exam.

An additional limitation is that we did not include potential moderating and mediating factors such as students' emotion regulation (Gross & John, 2003) or value appraisals (Pekrun, 2006). Although much less frequent in exam contexts (Pekrun et al., 2002), other intense negative emotions can also be related to spikes in cortisol. Future research should add self-report measures of test anxiety (Hoferichter et al., 2015), perceptions of stress (Salmela-Aro et al., 2009), and other achievement emotions (Pekrun et al., 2011). Additionally, we were unable to assess the degree to which interrupting students during the performance task to survey them about their expectancy for success and collect saliva samples impacted their arousal response. Future research should consider how these data collection procedures may impact students' experiences during the task. Finally, the participants in this study reflected both the homogeneous population of students at the university from which it came, as well as the broader racial, ethnic, and gender demographics of engineering students in the United States more broadly (e.g., Botella et al., 2019, Villanueva et al., 2019). The results cannot be generalized beyond this population. Future research should be conducted with a larger, more diverse sample to examine if these relations hold for the broader population.

Conclusions

In this study, we found a significant relation between change in an indicator of the physiological component of test anxiety, salivary cortisol, and expectancy for success in an authentic exam context. Many students showed anticipatory physiological arousal as indicated by HPA-axis activation before the exam. Consistent with prior research on cortisol and performance tasks (e.g., Spangler et al., 2002), most students returned to baseline cortisol level as the exam progressed. However, not all students' cortisol levels declined during the exam; students whose expectancies for success declined did not experience a return towards homeostasis. These findings have implications for those concerned about the possible health effects of exams. Our study suggests that low expectancies for success on a practice exam in an essential but challenging course are related to lack of cortisol recovery. Research has demonstrated that repeated acute physiological arousal has adverse health effects. Researchers argue that this may have to do with the inflammatory effects of cortisol itself (Sin et al., 2017). As such, future research should explore the possible health consequences of high stakes exams, a frequent occurrence, for engineering majors as well as other groups of students. The findings also speak to those seeking to support students in reducing their test anxiety. We argue that physiological arousal is part of many students' exam experiences. Interventions may need to address both objective physiological arousal and subjectively experienced anxiety. One example may be mindfulness-based interventions which have demonstrated positive effects on HPA axis arousal (Aguilar-Raab, et al., 2021).

References

Adams, R. E., Santo, J. B., & Bukowski, W. M. (2011). The presence of a best friend buffers the effects of negative experiences. *Developmental Psychology, 47*(6), 1786-1791. https://doi.org/10.1037/a0025401

Aguilar-Raab, C., Stoffel, M., Hernández, C., Rahn, S., Moessner, M., Steinhilber, B., & Ditzen, B. (2021). Effects of a mindfulness-based intervention on mindfulness, stress, salivary alpha-amylase and cortisol in everyday life. *Psychophysiology, 58*(12), e13937. https://doi.org/10.1111/psyp.13937

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control, 19*(6), 716–723. https://doi.org/10.1109/tac.1974.1100705

Barsegyan, A., Mackenzie, S. M., Kurose, B. D., McGaugh, J. L., & Roozendaal, B. (2010). Glucocorticoids in the prefrontal cortex enhance memory consolidation and impair working memory by a common neural mechanism. *Proceedings of the National Academy of Sciences, 107*(38), 16655-16660. doi:10.1073/pnas.1011975107

Botella, C., Rueda, S., López-Iñesta, E., & Marzal, P. (2019). Gender diversity in STEM disciplines: A multiple factor problem. *Entropy, 21*(1), 30. https://doi.org/10.3390/e21010030

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130*(3), 355–391. https://doi.org/10.1037/0033-2909.130.3.355

Dienes, K., Gartland, N., & Ferguson, E. (2019). The relationship between the cortisol awakening response and cortisol reactivity to a laboratory stressor. *British Journal of Health Psychology, 24*(2), 265-281. https://doi.org/10.1111/bjhp.12352

Duncan, T. E., & Duncan, S. C. (2009). The ABC's of LGM: An introductory guide to latent variable growth curve modeling. *Social and Personality Psychology Compass, 3*(6), 979–991. https://doi.org/10.1111/j.1751-9004.2009.00224.x

Eccles, J. S., & Wigfield, A. (2002). Motivational Beliefs, Values, and Goals. *Annual Review of Psychology, 53*(1), 109–132. doi:10.1146/annurev.psych.53.100901.135153

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology, (61)*, 101859. https://doi.org/https://doi.org/10.1016/j.cedpsych.2020.101859

Felt, J. M., Depaoli, S., & Tiemensma, J. (2017). Latent growth curve models for biomarkers of the stress response. *Frontiers in Neuroscience, 11*. https://doi.org/10.3389/fnins.2017.00315

Foley, P., & Kirschbaum, C. (2010). Human hypothalamus–pituitary–adrenal axis responses to acute psychosocial stress in laboratory settings. *Neuroscience & Biobehavioral Reviews, 35*(1), 91-96. https://doi.org/10.1016/j.neubiorev.2010.01.010

Goetz, T., Preckel, F., Pekrun, R., & Hall, N. C. (2007). Emotional experiences during test taking: Does cognitive ability make a difference? Learning and Individual Differences, 17(1), 3–16. https://doi.org/10.1016/j.lindif.2006.12.002

Granger, D. A., Fortunato, C. K., Beltzer, E. K., Virag, M., Bright, M. A., & Out, D. (2012). Focus on Methodology: Salivary bioscience and research on adolescence: An integrated perspective. *Journal of Adolescence, 35*(4), 1081–1095. doi:10.1016/j.adolescence.2012.01.005

Gross, J.J., & John, O.P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85(2),* 348-362. https://doi.org/10.1037/0022-3514.85.2.348

Hanneman, S. K., Cox, C. D., Green, K. E., & Kang, D. H. (2011). Estimating Intra- and Inter-Assay Variability in Salivary Cortisol. *Biological Research for Nursing, 13*(3), 243–250. https://doi.org/10.1177/1099800411404061

Harley, J. M., Lou, N. M., Liu, Y., Cutumisu, M., Daniels, L. M., Leighton, J. P., & Nadon, L. (2021). University students' negative emotions in a computer-based examination: the roles of trait test-emotion, prior test-taking methods and gender. *Assessment & Evaluation in Higher Education, 46*(6), 956-972. doi:10.1080/02602938.2020.1836123

Hoferichter, F., Raufelder, D., Ringeisen, T., Rohrmann, S., & Bukowski, W. M. (2015). Assessing the multi-faceted nature of test anxiety among secondary school students: An English version of the German Test Anxiety Questionnaire: PAF-E. *The Journal of Psychology*, 1-23. doi:10.1080/00223980.2015.1087374

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Joseph, N. T., Jiang, Y., & Zilioli, S. (2021). Momentary emotions and salivary cortisol: A systematic review and meta-analysis of ecological momentary assessment studies. *Neuroscience & Biobehavioral Reviews*, 125, 365–379. doi:10.1016/j.neubiorev.2021.02.042

Juster, R.-P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience & Biobehavioral Reviews, 35*(1), 2–16. https://doi.org/10.1016/j.neubiorev.2009.10.002

Kemeny, M.E., Shestyuk, A., 2008. Emotions, the neuroendocrine and immune systems, and health In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *Handbook of emotions* (pp. 661-675). Guilford Press

Kirschbaum, C., Pirke, K.-M., & Hellhammer, D. H. (1993). The "Trier Social Stress Test" – A Tool for Investigating Psychobiological Stress Responses in a Laboratory Setting. *Neuropsychobiology, 28*(1-2), 76–81. doi:10.1159/000119004

Kiuru, N., Spinath, B., Clem, A.-L., Eklund, K., Ahonen, T., & Hirvonen, R. (2020). The dynamics of motivation, emotion, and task performance in simulated achievement situations. *Learning and Individual Differences*, *80*, 101873. https://doi.org/10.1016/j.lindif.2020.101873

Labuschagne, I., Grace, C., Rendell, P., Terrett, G., & Heinrichs, M. (2019). An introductory guide to conducting the Trier Social Stress Test. *Neuroscience & Biobehavioral Reviews*, *107*, 686-695. doi:10.1016/j.neubiorev.2019.09.032

Lacey, K., Zaharia, M. D., Griffiths, J., Ravindran, A. V., Merali, Z., & Anisman, H. (2000). A prospective study of neuroendocrine and immune alterations associated with the stress of an oral academic examination among graduate students. *Psychoneuroendocrinology, 25*(4), 339-356. https://doi.org/10.1016/S0306-4530(99)00059-1

Lewis, F., Butler, A., & Gilbert, L. (2010). A unified approach to model selection using the likelihood ratio test. *Methods in Ecology and Evolution, 2*(2), 155–162. https://doi.org/10.1111/j.2041-210x.2010.00063.x

Linnenbrink-Garcia, L., Wormington, S. V., & Ranellucci, J. (2016). Measuring affect in educational contexts: A Circumplex Approach. In *Methodological Advances in Research on Emotion and Education* (pp. 165-178). Springer.

Mehta, P. D., & West, S. G. (2000). Putting the individual back into individual growth curves. *Psychological Methods, 5*(1), 23–43. https://doi.org/10.1037/1082-989x.5.1.23

Muthén, L. K., & Muthén, B. O. (1998-2017). *Mplus User's Guide. Eighth Edition.* Muthén & Muthén.

Office of Management and Budget; Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity, 62(210) Fed. Reg. 58782-58790 (Sept. 29, 1997)

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18*(4), 315–341. https://doi.org/10.1007/s10648-006-9029-9

Pekrun, R. (2018). Control-value theory: A social-cognitive approach to achievement emotions. In G. A. D. Liem, & D. M. McInerney (Eds.), *Big Theories Revisited 2: A Volume of Research on Sociocultural Influences on Motivation and Learning* (pp. 162-190). Information Age Publishing.

Pekrun, R. (2021). Self-appraisals and emotions: A generalized control-value approach. In T. Dicke, F. Guay, H. W. Marsh, R. G. Craven, & D. M. McInerney (Eds). *Self – a multidisciplinary concept* (pp. 1-30). Information Age Publishing.

Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary educational psychology*, *36*(1), 36-48. doi:10.1016/j.cedpsych.2010.10.002

Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist, 37*(2), 91-105. https://doi.org/10.1207/S15326985EP3702_4

Preacher, K. J., Wichman, A. L., MacCallum, R. C., & Briggs, N. E. (2008). *Latent Growth modeling*. Sage.

Putwain, D. (2007). Researching academic stress and anxiety in students: some methodological considerations. *British Educational Research Journal, 33*(2), 207–219. https://doi.org/10.1080/01411920701208258.

Ringeisen, T., Lichtenfeld, S., Becker, S., & Minkley, N. (2019). Stress experience and performance during an oral exam: the role of self-efficacy, threat appraisals, anxiety, and cortisol. *Anxiety, Stress, & Coping*, *32*(1), 50-66. doi:10.1080/10615806.2018.1528528

Roick, J., & Ringeisen, T. (2017). Self-efficacy, test anxiety, and academic success: A longitudinal validation. *International Journal of Educational Research*, 83, 84–93. https://doi.org/10.1016/j.ijer.2016.12.006

Roos, A. L., Goetz, T., Voracek, M., Krannich, M., Bieg, M., Jarrell, A., & Pekrun, R. (2020). Test Anxiety and Physiological Arousal: A Systematic Review and Meta-Analysis. *Educational Psychology Review, 33*(2), 579–618. https://doi.org/10.1007/s10648-020-09543-z

Salmela-Aro, K., Kiuru, N., Leskinen, E., & Nurmi, J.-E. (2009). School Burnout Inventory (SBI). *European Journal of Psychological Assessment, 25*(1), 48–57. doi:10.1027/1015-5759.25.1.48

Sanz, A., & Villamarín, F. (2001). The role of perceived control in physiological reactivity: self-efficacy and incentive value as regulators of cardiovascular adjustment. *Biol Psychol, 56*(3), 219-246. doi:10.1016/s0301-0511(01)00095-3

Schlotz, W. (2019). Investigating associations between momentary stress and cortisol in daily life: What have we learned so far? Psychoneuroendocrinology, 105, 105–116.

Schönfeld, P., Preusser, F., & Margraf, J. (2017). Costs and benefits of self-efficacy: Differences of the stress response and clinical implications. *Neuroscience & Biobehavioral Reviews, 75*, 40-52. doi:https://doi.org/10.1016/j.neubiorev.2017.01.031

Schoofs, D., Hartmann, R., & Wolf, O. T. (2008). Neuroendocrine stress responses to an oral academic examination: No strong influence of sex, repeated participation and personality traits. *Stress, 11*(1), 52–61. https://doi.org/10.1080/10253890701453943

Schwarz, G. (1978). Estimating the Dimension of a Model. *The Annals of Statistics*, *6*(2), 461–464. https://doi.org/10.1214/aos/1176344136

Shell, D. F., & Husman, J. (2001). The Multivariate Dimensionality of Personal Control and Future Time Perspective Beliefs in Achievement and Self-Regulation. *Contemporary Educational Psychology*, *26*(4), 481–506. https://doi.org/10.1006/ceps.2000.1073

Shell, D. F., & Husman, J. (2008). Control, motivation, affect, and strategic self-regulation in the college classroom: A multidimensional phenomenon. *Journal of Educational Psychology, 100*(2), 443–459. https://doi.org/10.1037/0022-0663.100.2.443

Sin, N. L., Ong, A. D., Stawski, R. S., & Almeida, D. M. (2017). Daily positive events and diurnal cortisol rhythms: Examination of between-person differences and within-person variation. Psychoneuroendocrinology, 83, 91–100

Spangler, G., Pekrun, R., Kramer, K., & Hofmann, H. (2002). Students' emotions, physiological reactions, and coping in academic exams. *Anxiety, Stress & Coping: An International Journal, 15*(4), 413–432. https://doi.org/10.1080/1061580021000056555

Stöber, J., & Pekrun, R. (2004). Advances in test anxiety research. *Anxiety, Stress & Coping, 17*(3), 205–211. https://doi.org/10.1080/1061580412331303225

Suresh, R. (2006). The relationship between barrier courses and persistence in engineering. *Journal of College Student Retention: Research, Theory & Practice, 8*(2), 215-239.

Szafranski, D. D., Barrera, T. L., & Norton, P. J. (2012). Test anxiety inventory: 30 years later. *Anxiety, Stress, & Coping, 25*(6), 667-677. doi:10.1080/10615806.2012.663490

Tilbrook A. J.2007. Neuropeptides, stress-related In G. Fink (Eds.), *Encyclopedia of stress* (pp. 903–908). Oxford, U.K.: Academic Press.

Tomczyk, S. & Hoferichter, F. (2021). Associations between social media use, psychological stress, well-being and alpha-amylase levels in adolescents. Journal of Stress, Trauma, Anxiety and Resilience (J-STAR)

Verschoor, E., & Markus, C. R. (2011). Affective and neuroendocrine stress reactivity to an academic examination: Influence of the 5-HTTLPR genotype and trait neuroticism. *Biological Psychology, 87*(3), 439–449. https://doi.org/10.1016/j.biopsycho.2011.06.001

Villanueva, I., Di Stefano, M., Gelles, L., Osoria, P. V., & Benson, S. (2019). A race re-imaged, intersectional approach to academic mentoring: Exploring the perspectives and responses of womxn in science and engineering research. *Contemporary Educational Psychology, 59*, 101786. https://doi.org/10.1016/j.cedpsych.2019.101786

von der Embse, N., Jester, D., Roy, D., & Post, J. (2018). Test anxiety effects, predictors, and correlates: A 30-year meta-analytic review. *Journal of Affective Disorders, 227*, 483-493. https://doi.org/10.1016/j.jad.2017.11.048

Table 1

Correlations, Means, and Standard Deviations for Observed Variables and Time

	1	2	3	4	5	6	7
1. E0	1.00						
2. E1	.68**	1.00					
3. E2	.52**	.67**	1.00				
4. C0	.05	.26	.27	1.00			
5. C1	-.09	.05	-.01	.33*	1.00		
6. C2	-.34**	-.03	.01	.16	.25	1.00	
7. C3	.11	.16	-.05	.20	.24	.42*	1.00
Mean	8.58	7.71	6.40	0.26	0.17	0.15	0.17
SD	1.48	1.99	2.28	0.15	0.07	0.07	0.11
Time mean	0.00	0.75	1.98	0.00	0.75	1.98	2.31
Time *SD*	—	—	0.56	—	—	0.56	0.56

Note. * $p < .05$. ** $p < .01$. E = Expectancy for success, C = Salivary Cortisol. Time measured in hours.

Table 2

Fit Indices and Parameter Estimates for Expectancy for Success (E) and Salivary Cortisol (S) in the Latent Growth Model (LGM) and the Combined Parallel Process Latent Growth Model (PP-LGC)

	Expectancy for success (E) LGM		Salivary cortisol (C) LGM			ExC PP-LGM
	Intercept-only	Linear	Intercept-only	Linear	Quadratic	PP-LGM
Fit indices						
Free parameters	5	8	6	9	13	27
Loglikelihood	-277.65	-254.72	168.76	175.01	185.93	-62.53
LRTS (df)[1]		45.86** (3)		12.50** (3)	21.84** (4)	
AIC	565.30	525.43	-325.51	-332.01	-345.85	179.06
ΔAIC		-39.87		-6.50	-13.84	
BIC	574.33	539.89	-314.67	-315.71	-363.12	227.84
Parameters						
Expectancy for success (E)						
Intercept $\mu_{E[I]}$	7.95** (0.39)	8.53** (0.24)				8.54** (0.24)
Linear slope $\mu_{E[L]}$		-1.06** (0.16)				-1.06** (0.16)
$\Psi_{E[I]}$	1.86** (0.71)	1.61** (0.55)				1.75** (0.54)
$\Psi_{E[L]}$		0.22 (0.33)				0.32 (0.30)
$\Psi_{E[I]xE[L]}$		0.35 (0.19)				0.19 (0.42)
ε_{E0}	1.44* (0.71)	0.77 (0.63)				0.54 (0.53)
ε_{E1}	1.53 (0.86)	1.29* (0.58)				1.41* (0.56)
ε_{E2}	5.41* (2.16)	2.27 (1.40)				2.16 (1.28)

Table 2 (continued).

	Expectancy for success (E) LGM		Salivary cortisol (C) LGM			ExC PP-LGM
	Intercept-only	Linear	Intercept-only	Linear	Quadratic	PP-LGM
Salivary Cortisol (C)						
Intercept $\mu_{C[I]}$			.164** (.009)	.197** (.013)	.252** (.021)	.250** (.022)
Linear slope $\mu_{C[L]}$				-.023** (.008)	-.126** (.036)	-.122** (.037)
Quadratic slope $\mu_{C[Q]}$					.035** (.013)	.034** (.013)
$\Psi_{C[I]}$			.002* (.001)	.002 (.002)	.017** (.006)	.017** (.006)
$\Psi_{C[L]}$				.001 (.001)	.040** (.015)	.040** (.015)
$\Psi_{C[Q]}$					.004** (.002)	.004* (.002)
$\Psi_{C[I]xC[L]}$				-.001 (.001)	-.025** (.009)	-.024** (.009)
$\Psi_{C[I]xC[Q]}$					.008** (.003)	.008* (.003)
$\Psi_{C[L]xC[Q]}$					-.013** (.005)	-.013* (.005)
ε_{C0}			.027** (.006)	.022** (.006)	.004 (.004)	.005 (.004)
ε_{C1}			.004** (.001)	.004** (.001)	.003** (.001)	.004** (.001)
ε_{C2}			.003** (.001)	.002 (.001)	.002 (.001)	.002 (.001)
ε_{C3}			.009* (.004)	.009 (.004)	.007 (.004)	.008 (.004)

Table 2 (continued).

	Expectancy for success (E) LGM		Salivary cortisol (C) LGM			ExC PP-LGM
	Intercept-only	Linear	Intercept-only	Linear	Quadratic	PP-LGM
Covariances						
$\Psi_{C[I]xE[I]}$						.023 (.035)
$\Psi_{C[I]xE[L]}$						.047* (.019)
$\Psi_{E[I]xC[L]}$						-.067 (.057)
$\Psi_{C[L]xE[L]}$						-.075** (.024)
$\Psi_{E[I]xC[Q]}$						.021 (.020)
$\Psi_{C[Q]xE[L]}$						.026** (.008)

Notes. * $p < .05$, ** $p < .01$. [1] Likelihood Ratio Test Statistic significance derived using difference in number of parameters and assuming a χ^2 distribution. μ_{Factor} = mean of latent variable. Ψ_{Factor} = variance/covariance of latent variables. [I] = intercept. [L] = linear slope. [Q] = quadratic slope. ε = residual variance of manifest variables. E = expectancy for success, C = cortisol. LGM = latent growth model, PP-LGM = parallel process latent growth model. AIC= Akaike information criterion, BIC = Bayesian information criterion. Higher Loglikelihood and lower AIC & BIC suggest better model fit for nested models. Standard errors reported within the parentheses after all parameter estimates. All parameters unstandardized.

Figure 1

Timeline for Study Visit Identifying Data Collection Method and Timing

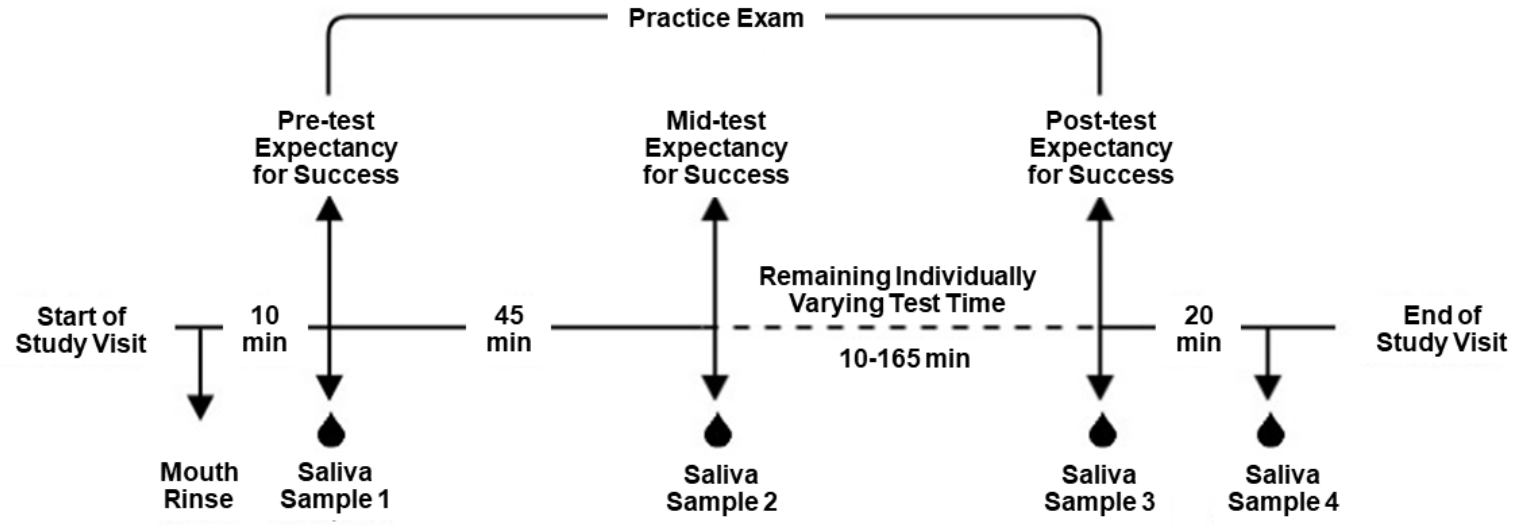
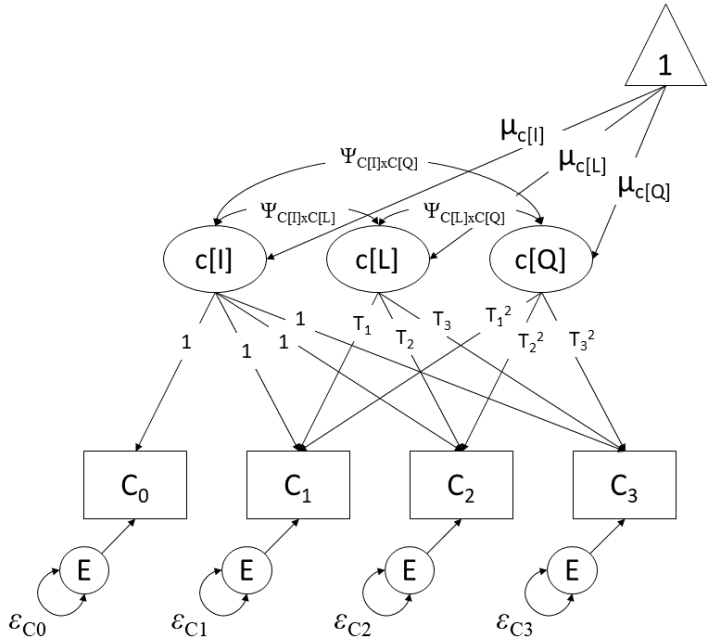


Figure 2

Path Diagram of Univariate Quadratic Latent Growth Model with Individually-Varying Times of Observation for Salivary Cortisol



Notes. μ_{Factor} = mean of latent variable. Ψ_{Factor} = variance/covariance of latent variables. C[I] = latent intercept cortisol. C[L] = latent linear slope cortisol. C[Q] = latent quadratic slope cortisol. T_x = time of observation for each wave. C_x = observed cortisol for each wave. ε_{CX} = residual variance of manifest variables for each wave.

Figure 3

Growth Trajectory for Predicted Change in Student µg/dl Salivary Cortisol (Blue) by Time Overlaid on Top of Observed Change in Salivary Cortisol

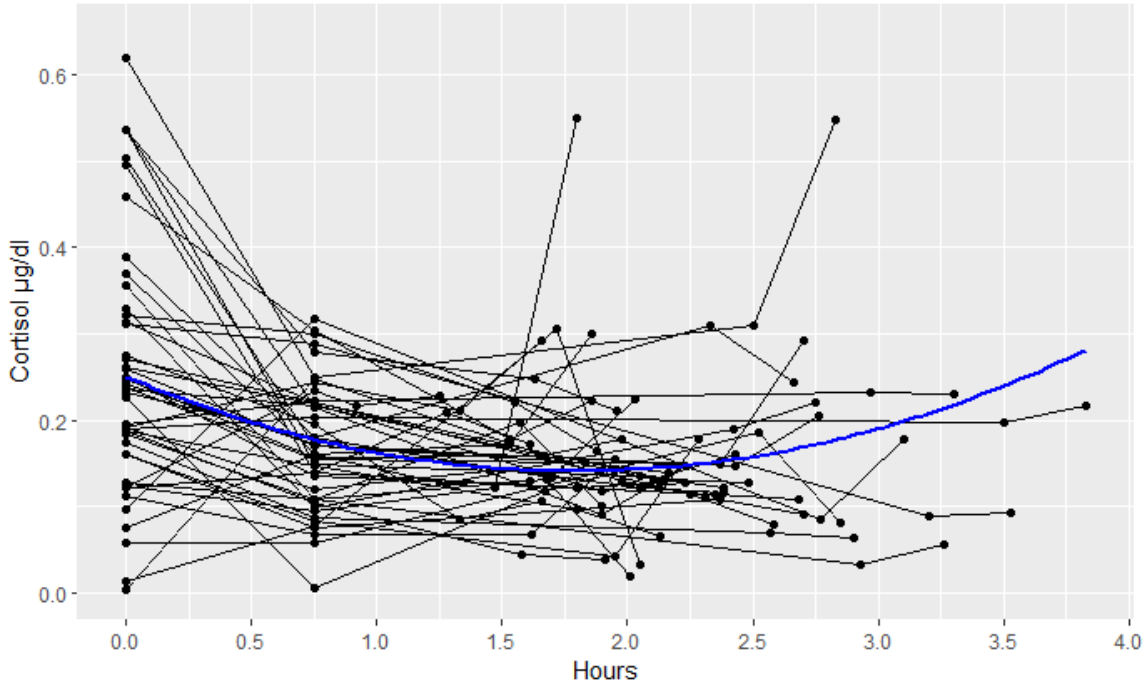


Figure 4

Growth Trajectory for Predicted Change in Expectancy for Success (Blue) by Time Overlaid on Top of Observed Change in Expectancy for Success