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Understanding Engineering Students Stress and Emotions during an Introductory Engineering course.

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Although recent literature in engineering education has focused on student enjoyment of coursework and its influence on student retention, [1-3] very little research has incorporated theoretical frameworks which identify the specific roles that student beliefs and emotions play in course engagement. [4] To supplement self-report measures when assessing students' emotions in learning environments, many educational researchers have attempted to tie physiological responses to students' beliefs, affects, and motivation – including those that utilized self-reported bodily responses, brain imaging, galvanic skin responses, and cardiovascular responding. [5-12] Some researchers in education, but not many, have utilized the biological marker salivary cortisol to indicate students' stress and emotional states. [13, 14]

Notably, a multi-method interdisciplinary approach in *engineering* educational research has yet to be established. Interdisciplinary work, however, is crucial for incorporating theories with practice in education, since the inclusion of biomarkers in emotion-and-motivation-related research could provide support for current theory and its application, to enhance learning and course engagement. Using salivary cortisol as a tool in engineering educational research allows us to take advantage of saliva's sampling convenience, and its informative nature that is not readily affected by social desirability, reactivity, and memory. In essence, the current study aimed to address two gaps in the engineering educational literature: 1) to bridge research in engineering students' beliefs and emotions with theory, and 2) to explore an interdisciplinary approach to understanding how engineering students engage in their courses using salivary cortisol.

Theoretical frameworks

The field is gravitating towards an understanding and acceptance of the roles that motivation, beliefs, and emotions play in engineering education. [4, 15] However, theory-based empirical research is much needed in order to tease apart the mechanisms of how each psychological construct is associated with another. In the current study, we used two motivational frameworks: Control-Value Theory (CVT) [16, 17] and Future Time Perspective Theory (FTPT). [18] CVT addresses the multi-faceted nature of emotions (affective, cognitive, motivational, and physiological), and posits that specific academic emotions influence students' use of successful learning strategies, persistence during difficult learning tasks, and academic achievement. FTPT contends that individuals have substantial individual differences in their perceptions of time and extension of thinking across time.

Control Value Theory. Academic achievement emotions refer to those that are related to academic learning and achievement, such as enjoyment, hope, pride, anxiety, shame, and anger. They have been found to be associated with students' educational outcomes including motivation, learning strategies, cognitive resources, and academic achievement. [19, 20] Research on academic achievement emotions was derived from the Control-Value Theory (CVT), which marries emotional research with motivational research. [16, 17, 21] According to CVT, the situational contexts that students find themselves in are important when examining students' emotions. The theory proposes that students may experience either test-related, class-related, or learning related-emotions that involve multiple-component processes, including affective, physiological, motivational, and cognitive components. CVT also suggests that academic achievement emotions are affected by appraisal antecedents of students including: (a) subjective control over achievement activities and outcomes and (b) the subjective values of these tasks, activities and outcomes. For example, in terms of *subjective control*, students who feel more in control of the class materials may experience more positive emotions in learning. Previous research has also shown that college students' beliefs about their inability to control learning or how well they do in class predicted shame reactions to test feedback. [22] In terms of *subjective task value*, students who place more value in mastering a particular class may be more emotionally charged for the class activities and outcomes. [16, 21]

Future Time Perspective Theory (FTPT). In motivational research, Future Time Perspective (FTP)**,** which is described as humans' perceptions about the future and ability to consider the future, has been found to be an important motivational construct that enhances learning, and promotes intrinsic motivation and active learning. [23, 24] Time perspective research shows that FTP is a multi-dimensional construct. [18, 24, 25] In a construct validity study, four dimensions for FTP were found including: (1) *connectedness*, the tendency to anticipate future consequences and to make cognitive connections between the present and the future; (2) *valence*, the tendency to place value in future goals; (3) *extension*, which refers to how far thoughts are projected into future; and (4) *speed*, which relates to the quickness by which individuals feel time passing. [26] The dimensions of connectedness and valence were found to be positively related to control beliefs. [27] It would make sense that FTP could also be an appraisal antecedent, playing a role in students' beliefs as described in CVT, contributing to academic achievement emotions.

Students normally have a few long-term career goals but characterizes students with strong FTP is their goals that are accompanied with well-devised plans and directions, whereas students with weak FTP have goals that are un-substantiated and fantasy-based. Students' time perspectives allows them to imagine the goal fully and feel an emotional connection to both the value of completing particular present tasks and future goals *and* their ability to make connections between these tasks and future goals. Students who are able to imagine their future fully in the present and connect those thoughts to decisions in the present has consistently demonstrated positive educational and personal outcomes. [18, 24]

Perceptions of Instrumentality. In FTPT research, perceptions of instrumentality (PI) refers to students' perceptions of whether a future goal is contingent upon a current action or task, in other words, whether a task has instrumental value for a future goal. [28] For example, an engineering major may view gaining an internship as instrumental for their professional goal attainment. Researchers suggested that PI may be related to students' *instrinsic* task value (personal interests and relevance), in addition to *extrinsic* value (utility) of a task. Perceived instrumentality can be divided into two sub-dimensions: (1) *endogenous PI*, the perception of whether learning and mastering new information would be intrinsically useful towards reaching a future goal, regardless of their utility in attaining external rewards; and (2) *exogenous PI*, the perception that learning and the student's future goals are linked through external rewards such as course grades. [29] Endogenous PI incorporates both students' future-oriented and intrinsic motivation. [28, 18] PI has been found to be related to students' academic achievement, [30] goal orientation, [31] volitional strategies used, [29] better learning strategies, and academic performance. [32] In particular, Hilpert et al. found that endogenous PI was associated with deep information processing in post-secondary engineering students. [33]

Given its intrinsically motivating nature, it is plausible that endogenous PI can act as an appraisal antecedent in predicting positive academic achievement emotions. Notably, endogenous PI is derived from FTPT; however, it is task and context specific. Each immediate academic task could be deemed as a facilitator for a future goal. It is thus plausible that the context specific positive emotions (as suggested by CVT) [17] could be predicted by endogenous PI.

Salivary cortisol in educational settings

The sampling of salivary biomarkers has become a popular means to understand physiological underpinnings or manifestations of individuals' responses to various stressors in developmental and social psychology. Literature is consistence with the multi-faceted nature CVT had described for emotions. However, salivary biomarkers in educational settings, specifically those that pertain to positive emotions, are yet to be explored. A multi-method approach will allow engineering education researchers to have a more detailed picture of the motivational beliefs, emotional responses, and emotional regulation students experience. Strong evidence for the influence of beliefs on emotions will allow the research community to take the next step, developing support structures to reduce student distress, assist them in recovery from negative emotions (e.g., shame or fear). To provide this strong evidence, however, we argue that a combination of biological and self-report measures are needed.

A plethora of topics have been explored for salivary biomarkers, including research in response to cognitive/academic abilities and salivary biomarkers in young children. [35] Specifically, young children showed lower executive function skills when both cortisol (an HPA-axis end product) and salivary alpha amylase (sAA, an LC-NE/SNS by-product) [34] were high and showed higher academic abilities when high sAA is accompanied with low to moderate cortisol levels. [35] Conversely, other researchers found curvilinear interactions between sAA and cortisol in predicting cognitive functioning and academic performances in children, with highest and lowest child functioning predicted by moderate levels of physiological arousal. [36] Cortisol has also been found to be associated with emotion regulation in children, with preschoolers' cortisol reactivity positively related to regulation. [37] In adult learners, a meta-analysis showed that emotions were predictive of cortisol responses to social evaluative threat; specifically, surprise, worry, and fear. [38] Spangler, Pekrun, Kramer, & Hofmann found predictions of test-related negative emotions to university students' cortisol responses. [13] Thus, we posited that emotional components and its appraisal antecedents (e.g., subjective control) will be dually reflected in the bio-manifestations of students' salivary profiles, represented by saliva cortisol in the current study. In particular, academic positive emotions should be related to a lower manifestation of the stress.

Research hypotheses

We suspected that students' beliefs about the value of a course for their future as engineers have an impact on students' academic emotions. We also proposed that these beliefs and emotions would be jointly reflected in the bio-manifestations of students' salivary profiles, represented by saliva cortisol. [39]

We hypothesized that student's class-related positive emotions would negatively correlated with students' cortisol levels; we also hypothesized that students' endogenous PI would positively predict their positive emotions, and would negatively predict their cortisol levels. While research has demonstrated that cortisol levels in human saliva are good predictors of a biological response to stress and discomfort, few studies have explored the associations between cortisol levels and positive emotions, specifically enjoyment, or future-oriented motivation, bringing significance to the current study.

Method

Participants

Our participants were recruited in an engineering ethics course at a public university in the Southwest of the US. Among the 52 students in the in the sampled class, 31 consented to participate in our study. 29 out of the 31 students who consented had pre-and-post class data (two students dropped out before class ended), leaving us with a 55.77% study participation rate.

Out of the 29 valid participants, 6 were female (20.69%). In terms of race/ethnicity, 6.9% were American Indian, 13.8% were Asian, 27.6% were Hispanic, 3.4% were Black, 41.4% were White, 3.4% were Pacific Islander, and 10.3% were Multiracial/multi-ethnic. The diversity of the sample was representative of the ASU Engineering program population. [40]

Procedures

All procedures were approved by the university institutional review board prior to data collection. Two validated self-report measures of achievement emotions and perceptions of the value of a course for future goals were used. Procedures regarding saliva collection specifically followed best practices guidelines provided by the Institution of Interdisciplinary Salivary Bioscience Research (IISBR) at Arizona State University.

Upon entering the classroom, students were given a packet of materials that described the study. This packet also included a saliva collection kit, a self-report survey, consent form and a bottle of water. The saliva collection kit contained two oral swabs and two collection vials marked with the participants' unique identification code. After collecting signed consent forms, a researcher explained the saliva collecting process and instructed students to rinse their mouths with water and to place the oral cotton swab under their tongue (to obtain sublingual saliva) for two minutes. Students then filled out the first part of the self-report survey, including: a) the class-related Achievement Emotions Questionnaire (AEQ) for pre-class enjoyment, e.g., "I get excited about going to class", and b) endogenous Perceptions of Instrumentality (en PI), e.g., "I will use the information I learn in CEE 181 in other classes I will take in the future". After the two minutes, the participants tongued the cotton swab into the vial and sealed it. Research assistants then collected this first sample and placed it in a cooler at approximately 4 ℃.

At the end of the class, the students were instructed to repeat the saliva collection process and to resume the self-report survey (class-related AEQ for post-class enjoyment).

Students returned their second saliva sample and survey to the RAs and were paid $5 for their participation. Two students left class early and were deleted listwise from the study, prior to the analysis. The RAs placed the second saliva sample in the cooler. Immediately after class, the samples were taken on ice directly to the IISBR at Arizona State University where they would be stored and assayed for salivary cortisol.

Measures

Academic Achievement Emotions. Achievement Emotions Questionnaire (AEQ; 1 = Strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = Strongly agree) was included in students' self-reports. The AEQ short version contained 10 Class-related emotions items for positive emotions. [21] Sample items for Class-related emotions include *"I get excited about going to class"* (pre-class enjoyment), and *"After class I start looking forward to the next class"* (post-class enjoyment). 4 items that pertain to pre-class positive emotions were measured at the beginning of the class period, and 6 items that pertain to post-class positive emotions were measured at the end of class.

Perceptions of Instrumentality. The students' self-reports will include the Perceptions of Instrumentality Scale (PI; 1 = Strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = Strongly agree): The perceptions of instrumentality scale assessed endogenous PI (4 items) and exogenous PI (4 items). [28] The scale will include endogenous items, such as, *"What we gained from this class will shape my future"* and exogenous items, such as, *"The only aspect of this class that will matter after graduation is my grade."* PI was measured at the beginning of the class.

Salivary Cortisol. Salivary cortisol was collected before and after class. The Research Assistants (RAs) trained students how to collect their samples when they consented at the beginning of class. The 1st sample was taken at the beginning of class along with the pre-class survey, and was handed to the RAs for icing. The 2nd sample was taken immediately after class. Saliva samples were immediately stored in ice chests that the RAs brought to the classroom. All samples were be stored in low temperature ice chests during transportation or shipping to the Institute for Interdisciplinary Salivary Bioscience Research at Arizona State University for assays, and were put in -20^{o}C storage until the assays. Salivary cortisol was assayed by a highly sensitive enzyme immunoassay, and reported in micrograms per deciliter (g/dl). [41]

Results

Correlations

In general we found meaningful and significant correlations between class-related positive emotion (enjoyment), students' endogenous perceptions of instrumentality (PI) and cortisol levels. Enjoyment positively correlated with endogenous PI, and negatively correlated with cortisol levels (see Table. 1).

More specifically, endogenous PI significantly positively correlated with both pre-class and post-class enjoyment (*rs* = .72, .63 respectively; $ps < .001$). Pre-class cortisol significantly positively correlated with post-class cortisol (r = .74, $p < .001$), significantly negatively correlated with pre-class enjoyment (r = -.46, $p < .05$), and marginally negatively correlated with Endogenous PI (r = -.35, $p < .10$). Post-class cortisol was significantly negatively correlated with pre-class enjoyment (r = -.37, p < .05), and was also marginally negatively correlated with Endogenous PI (r = -.35, $p < .10$).

Multiple Regression Models

Results showed that post-class enjoyment was predicted by endogenous perceptions of instrumentality, above and beyond pre-class cortisol levels (adjusted $R^2 = .36$, $R^2 = .33$, $p < .001$), explaining approximately 40% of the variance in post-class enjoyment. Post-class cortisol was significantly predicted by pre-class enjoyment (adjusted $R^2 = .103$, B = -.022, SE = .011, $Z_B = -.367$, $p < .05$).

Table 1

Correlations between students' endogenous PI, pre-and-post class enjoyment and salivary biomarkers.

	1	2	3	4	5	6	7
1 Cortisol (pre)	--						
2 Cortisol (post)	.74**	--					
3 sAA (pre)	.35$^+$	.05	--				
4 sAA (post)	-.14	.127	.83**	--			
5 Joy (pre)	-.46*	-.37*	-.12	-.10	--		
6 Joy (post)	-.28	-.06	.03	.17	.78**	--	
7 En PI	-.35$^+$	-.35$^+$	-.10	-.01	.72**	.634**	--

8 Observation	.224	.10	.08	-.18	.13	.03	.27

Note: +, $p < .10$; *, $p < .05$; **, $p < .01$ (2-tailed).

Table 2

Regression models predicting post-class enjoyment. Model 1: pre-class cortisol predicting post-class enjoyment was in the hypothesized direction but non-significant. Model 2: above and beyond pre-class cortisol levels, pre-class endogenous PI was a better predictor for post-class enjoyment.

		Unstandardized		Standardized			95% CI for B	
							Lower	Upper
Model		*B*	*SE*	*Beta*	*t*	*p*	Bound	Bound
1	(Constant)	4.166	0.349		11.927	0.00	3.448	4.884
	Pre-class cortisol	-2.571	1.700	-0.284	-1.513	0.142	-6.064	0.923
2	(Constant)	0.530	1.022		0.519	0.608	-1.574	2.635
	Pre-class cortisol	-0.659	1.485	-0.073	-0.444	0.661	-3.718	2.399
	Endogenous PI	0.182	0.049	0.609	3.706	0.001	0.081	0.283

Discussion

This study explored engineering students' cognitive, emotional, and biological responses to an ethics course. Specifically, we found that class-related positive emotions at the beginning of class negatively correlated with students' cortisol levels at the end of class, indicating that the more self-reported enjoyment a student experienced in class, the lower their physiological stress levels. In addition, students' value of the class for achieving future goals (endogenous PI before class) positively predicted students' enjoyment after class, suggesting that students' perception of a class as valuable for achieving a future goal can predict the positive emotions they experience in class.

In engineering education, students may experience an array of emotions while striving to achieve their goals, be it for a proximal academic exam, or for a more distant career goal. In a qualitative study, [42] Sunderland suggested that problem-based learning integrated engineering students' understanding of engineering ethics with moral emotions, and enabled students to better pin down their societal roles as future engineers. While the work hinted the links between students' emotions and their learning experiences, the research did not provide theoretical or statistical grounding for these associations. In a personality perspective investigation, future-oriented time perspective was found to be positively associated with Filipino university students' positive academic achievement emotions (hope, joy, and pride), as well as anxiety, linking FTP to academic achievement emotions. [43] However, few studies have examined dimensional FTP jointly with academic achievement emotions and physiological affective responses, specifically in the field of post-secondary engineering education, making our current work unique and valuable.

Our results help confirm that if educators/teachers incorporate future thinking into engineering educational programs, students may be better motivated to work towards their academic goals in engineering studies. By nurturing emotional and physical health in Engineering students, the nation's future Engineers and scientists will become more resilient and resourceful in facilitating science progression. Moreover, findings may be informative for engineering educators, in that social/environmental influences on each student could mold their academic achievements. Such understandings help educators gain focus on ways to best benefit their students' needs.

Limitations and future directions

Deducting from the results of the study, we posit that the effect of beliefs on emotions, and the effect of emotions on biological responses may form a mediation effect, with emotions as the mediator. As the current study has a limited sample size, we suggest future research to examine such mediation effect via examining multiple time point in a larger sample, or by using boot-strapping statistical techniques, to support the importance of students' beliefs about the future on enhancing their emotional and physical experiences. Such research is important in providing information on future intervention programs for engineering education.

We also suspect that students' future time perspective (Connectedness), [26] students' self-efficacy, [44] and students' emotion regulation [45, 46] may play moderating roles in these associations. Future research will help us explore these potential moderation effects.

In conclusion, the current study provides methodological possibilities for understanding students' responses to instruction using both bio-markers and self-report. By utilizing the convenient biomarker, salivary cortisol, it is possible to investigate students' actual experiences before, during, and after class with a multi-method approach, which opens a new window to research in engineering education. Assessment of engineering students' abilities to imagine their future while connecting decisions in the present will be invaluable to this work as recent studies have pointed to the importance of linking engineering students' interests and values to immediate and long-term engineering career goals for professional success. [47, 48]

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