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BRIEF REPORT

# Cardiovascular measures independently predict performance in a university course

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**Abstract**

The factors that predict academic performance are of substantial importance yet are not understood fully. This study examined the relationship between cardiovascular markers of challenge/threat motivation and university course performance. Before the first course exam, participants gave speeches on academics-relevant topics while their cardiovascular responses were recorded. Participants who exhibited cardiovascular markers of relative challenge (lower total peripheral resistance and higher cardiac output) while discussing academic interests performed better in the subsequent course than those who exhibited cardiovascular markers of relative threat. This relationship remained significant after controlling for two other important predictors of performance (college entrance exam score and academic self-efficacy). These results have implications for the challenge/threat model and for understanding academic goal pursuit.

**Descriptors:** Cardiovascular reactivity, Challenge and threat motivation, Goal pursuit, Academic performance

Motivated goal pursuits are some of the most important situations that people face. The academic domain is replete with examples: Students must actively prepare for and complete assignments, papers, and exams to reach the valued goal of good performance in the short term and to further educational and career goals in the long term. The substantial subjective importance of these outcomes—to both the student and others—places a premium on understanding the factors that predict academic performance. Although an industry of standardized testing is devoted to predicting academic performance in college, research suggests that other untapped psychological and psychobiological constructs may also be critical.

In the current study, we tested the extent to which the cardiovascular markers of challenge/threat motivational states (Blascovich, 2008) predict future performance in a college course. Blascovich, Seery, Mugridge, Norris, and Weisbuch (2004) found that these cardiovascular markers predicted athletic performance, but they did not attempt to establish that the cardiovascular markers predicted performance independently of other demonstrated predictors. Thus, in addition to extending previous work to the academic domain, we assessed the unique contribution of cardiovascular markers above and beyond two such demonstrated predictors: standardized college entrance exam performance (SAT score; Sackett, Kuncel, Arneson, Cooper, & Waters, 2009) and self-reported academic self-efficacy (Chemers, Hu, & Garcia, 2001).

According to the biopsychosocial model of challenge/threat (Blascovich, 2008; Blascovich & Tomaka, 1996), people who are psychologically engaged in a motivated performance situation experience a psychological state along a bipolar continuum anchored by challenge and threat. *Challenge* occurs when evaluated personal resources are relatively high and situational demands are low, whereas *threat* occurs when demands are relatively high and resources are low. The evaluations that determine challenge/threat are affective as well as cognitive and need not be rational or conscious (e.g., they are affected by subliminal stimuli; Weisbuch-Remington, Mendes, Seery, & Blascovich, 2005).

Although challenge/threat can be assessed with self-report measures, doing so presents disadvantages. For example, people may not be able to reflect accurately on their inner states and experiences regarding motivational states (e.g., Nisbett & Wilson, 1977), especially to the extent that nonconscious and irrational influences are affecting them. Also, the process of interrupting individuals and directing their attention to a self-report measure could itself alter challenge/threat responses. Because cardiovascular measures do not rely on participants' conscious attention, they can avoid such limitations. For example, cardiovascular markers of challenge/threat vary more closely with relatively uncontrollable than with relatively controllable nonverbal responses (Weisbuch, Seery, Ambady, & Blascovich, 2009).

The cardiovascular responses associated with challenge/threat do not equate to challenge/threat itself, but instead rep-

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resent an indirect measure of the underlying psychological state. We used four cardiovascular measures to index challenge/threat: heart rate (HR); pre-ejection period (PEP), an index of left ventricular contractile force; cardiac output (CO), the amount of blood pumped by the heart (in liters per minute); and total peripheral resistance (TPR), an index of net constriction versus dilation in the arterial system. In the context of a motivated performance situation, an increase in HR and a decrease in PEP from baseline are common across the challenge/threat continuum. Given this reactivity, challenge is marked by higher CO and lower TPR than threat, such that relatively higher CO and lower TPR reflect relatively greater challenge or lesser threat.

These cardiovascular responses have been validated as markers of challenge/threat (for a review, see Blascovich, 2008) and have been employed successfully in several dozen studies examining various psychological processes, including religious belief systems (Weisbuch-Remington et al., 2005), stereotype threat (Vick, Seery, Blascovich, & Weisbuch, 2008), self-esteem (Seery, Blascovich, Weisbuch, & Vick, 2004), and defensive pessimism (Seery, West, Weisbuch, & Blascovich, 2008). The theoretical underpinnings for these cardiovascular changes derive from Dienstbier's (1989) model of psychophysiological toughness, specifically, differential activation of the sympathetic-adrenomedullary (SAM) and pituitary-adrenocortical (HPA or PAC) axes. Both challenge and threat are hypothesized to result in heightened SAM activation, but threat is believed to also result in heightened HPA activation, which may inhibit the epinephrine-mediated vasodilation that would otherwise occur (Blascovich, 2008).

Previous research has provided evidence for a link between cardiovascular markers of challenge/threat and performance quality. In the laboratory, cardiovascular markers of challenge (relative to threat) are typically (but not always) associated with superior performance (e.g., Blascovich, Mendes, Hunter, & Salomon, 1999). Blascovich et al. (2004) demonstrated that challenge/threat experienced in the laboratory predicted subsequent real-world performance. College baseball and softball players gave two speeches in the laboratory several months prior to the start of their varsity season. In the sport-relevant speech, the athletes imagined and spoke about playing in a critical game situation. In the sport-irrelevant speech, they spoke about various aspects of friendship. Cardiovascular markers of challenge/threat were recorded during these speeches and—at the close of the subsequent athletic seasons—were used to predict performance statistics. The sport-irrelevant speech was included as a statistical control designed to account for responses to speech-giving itself, thus isolating the component of reactivity attributable to the content of the speech topic (athletic performance). Results revealed that athletes who exhibited cardiovascular markers of challenge during the sport-relevant speech performed better during the subsequent season relative to those who exhibited cardiovascular markers of threat.

Applying the methodology of Blascovich et al. (2004) to the academic domain, we expected cardiovascular markers of challenge/threat exhibited by students while speaking about academic course-relevant topics to predict subsequent college course performance. As demonstrated in the prior study, we assumed that the speech topic would affect cardiovascular markers of challenge/threat beyond the effects of giving a speech in general (also see Weisbuch-Remington et al., 2005). We sought to isolate challenge/threat cardiovascular responses to two important aspects of academic performance: pursuing academic interests at the university level and demonstrating knowledge on tests. We recorded cardiovascular markers of challenge/threat during two speeches, one relevant to each topic, and entered both speeches simultaneously in statistical models. The component of challenge/threat cardiovascular reactivity resulting from the act of giving a speech should have been common to the two speeches and therefore could be removed statistically. This strategy allowed us to separate and compare the importance of these two aspects for predicting performance. Students who subsequently achieve greater course success should be more likely than those who achieve less success to be more comfortable (i.e., experience relatively high resources, low demands, and thus challenge) at the prospect of university study and test taking in general, thus creating an association between cardiovascular markers of challenge/threat and course performance.

Further extending Blascovich et al. (2004), we tested the extent to which the cardiovascular markers of challenge/threat predicted subsequent course performance uniquely, above and beyond two other demonstrated predictors: (1) SAT score, a measure of performance on a previous multiple-choice format exam (consistent with the exam format in the assessed course) that is widely used as a diagnostic tool in college admissions and predicts college performance (Sackett et al., 2009), and (2) academic self-efficacy, which refers to confidence in one's abilities to attain goals in the academic domain and has been found to predict future academic performance in first-year college students, even when controlling for previous performance (Chemers et al., 2001). This strategy presents a stringent test for challenge/threat in that both past success and self-reported confidence in academics could plausibly contribute to and overlap with challenge/threat responses. If cardiovascular markers of challenge/threat do not predict performance uniquely, it would suggest a large degree of meaningful overlap with other measures and little practical benefit for applying challenge/threat to this purpose. However, if cardiovascular markers of challenge/threat do predict performance uniquely, it would represent a significant advance for the challenge/threat model and suggest that this methodology captures important components of academic goal pursuit.

## Method

### *Participants*

Ninety-five undergraduates (42 women, 53 men) participated in the study for introductory psychology course credit.[1]

[1]In addition to the 95 participants who completed all elements of the study, 40 more had missing data and were excluded from primary analyses: 16 because they yielded cardiovascular data that were impossible to score reliably due to poor impedance cardiograph (ICG) signal quality; 11 because they did not report SAT scores; 6 because of blood pressure malfunction; 3 because they failed to complete the psychology course; 1 because of experimenter error; 1 because of disconnected electrode; 1 because that person elected not to participate; and 1 because that person failed to follow instructions. The two most common causes of missing data were unusable ICG data and lack of SAT score. First, in our experience, speech tasks (there were two in this study) tend to yield both particularly high reactivity values and participant fidgeting, which in combination results in a higher incidence of poor ICG quality than other tasks. Still, in this study there were an unexpectedly high number of poor-quality ICG signals. Given that data were collected early in the academic term in order to complete it before the first course exam, a likely contributor was inexperience among research assistants: a logistic regression demonstrated that data collected earlier in the study were more likely to be too poor of quality to be scored (i.e., rank order of participation predicted

***Cardiovascular Measures***

Cardiovascular measures were recorded noninvasively, following accepted guidelines (Sherwood et al., 1990) and utilizing a Minnesota Impedance Cardiograph (Model 304B) and a Cortronics (Model 7000) continuously inflated blood pressure monitor. Signals were conditioned using Coulbourn amplifiers and were stored on a desktop computer.

Impedance cardiograph (ICG) and electrocardiograph (EKG) recordings provided continuous measures of cardiac performance. The impedance cardiograph utilized a tetrapolar aluminum/mylar tape electrode system to record basal transthoracic impedance (Z0) and the first derivative of impedance change (dZ/dt), sampled at 1 kHz. EKG signals were detected using either a Standard Lead II electrode configuration (additional spot electrodes on the right arm and both legs) or through the band electrodes. The Cortronics blood pressure monitor collected continuous noninvasive recordings of blood pressure from the brachial artery of participants' nondominant arm. In combination, ICG and EKG recordings allowed computation of HR, PEP, and CO; the addition of blood pressure monitoring allowed computation of TPR (mean arterial pressure $\times$ 80/CO; Sherwood et al., 1990). The recorded data were ensemble averaged in 60-s intervals and scored using an interactive MS-DOS software program (Kelsey & Guethlein, 1990). Scoring was performed blind to other participant data.

***Procedures***

Participants reported SAT scores in mass-testing sessions at the beginning of the academic term. Participants were then scheduled for individual laboratory sessions before the first course exam. Upon participants' arrival, an experimenter applied necessary physiological sensors. After the experimenter left the testing room, participants listened to an audio recording instructing them to sit quietly until they received further instructions. Subsequently, 5 min of baseline data were recorded.

Following the baseline period, participants gave the first of two 2-min speeches, one about their academic interests and one about test taking, the order of which was counterbalanced (no effects were found for speech order, so it was excluded from analyses). Before each speech, participants heard audiotaped instructions that explained what they should discuss. For the academic interests speech, participants were asked to discuss "what subject areas interest you, why you are interested in these areas, and what classes you want to take in the future." For the test-taking speech, participants were asked to imagine themselves about to take an exam and discuss "how you feel about being in this situation (i.e., the imagined exam), what you are thinking about at this time, and how you expect to perform and why." Because we wanted to assess individual differences, it was important that participants be able to experience their reactions to the topics as naturally as possible. They were thus allowed to generate their own speeches within the constraints of each topic, even though this sacrificed some experimental control over speech content. The instructions made no mention of psychology in general or the psychology course used to measure performance. We designed the two speeches to focus on two distinct components of academic performance: pursuing academic interests at the university level and demonstrating knowledge on tests. If participants stopped speaking before 2 min had elapsed, the experimenter prompted them via intercom with the relevant speech themes. Participants rested for a second 5-min baseline period between speeches.

After the second speech, an experimenter entered the testing room and gave participants the academic self-efficacy scale (Chemers et al., 2001), which included eight statements (e.g., "I usually do very well in school and at academic tasks"; $\alpha = .78$) with a 7-point Likert-type scale. Finally, all sensors were removed, each participant was thoroughly debriefed, and participants were asked for permission to obtain their introductory psychology course scores (i.e., total points on all exams in the course) from the instructor at the end of the term. Participants were not informed of their individual cardiovascular responses.

being unscorable; odds ratio = 0.98, $p = .014$). Second, regarding SAT scores, it could be argued that certain types of students—such as those who performed particularly poorly—should be more likely to either not recall or not wish to report their SAT scores. This could limit the generalizability of the current findings.

**Results**

We examined reactivity for all cardiovascular variables, subtracting the final minute of the initial baseline period from the mean of the 2 min for each speech. All tests were two-tailed, $\alpha = .05$. See Table 1 for a correlation matrix and descriptive statistics. Because HR and PEP reactivity are necessary components of the constellation of cardiovascular markers of challenge/threat, we first established that, in the sample as a whole, HR increased and PEP decreased from baseline during both speeches (i.e., reactivity value greater and less than zero, respectively): during the academic interests speech, HR $t(94) = 15.34$, $p < .001$, and PEP $t(94) = -7.71$, $p < .001$; during the test-taking speech, HR $t(94) = 16.02$, $p < .001$, and PEP $t(94) = -7.60$, $p < .001$.

Because changes in CO and TPR—which reveal reactivity consistent with relative differences in challenge/threat—should reflect the same underlying SAM versus HPA activation, we combined CO and TPR into a single index by converting participants' CO and TPR reactivity values for each speech into z-scores and summing them (see Blascovich et al., 2004). We assigned CO a weight of +1 and TPR a weight of $-1$ (i.e., TPR was reverse scored), such that a larger value corresponded to reactivity consistent with greater challenge. Using this index allowed us to maximize reliability of the cardiovascular measures and simplify analyses by conducting one test of challenge/threat reactivity predicting academic performance instead of separate CO and TPR analyses.

In separate bivariate correlations, the associations between each of the four predictors of primary interest and total performance at the end of the academic course were tested (see Table 1). As expected, cardiovascular reactivity consistent with greater challenge during the academic interest speech, higher academic self-efficacy, and higher SAT score all predicted significantly better performance; in contrast, cardiovascular markers of challenge/threat from the test-taking speech failed to predict performance significantly. To determine the unique contribution of each predictor, we entered them simultaneously in a single regression, which yielded the same pattern of significance as in the bivariate correlations: Cardiovascular reactivity consistent with greater challenge during the academic interest speech, higher self-efficacy, and higher SAT score predicted better performance (see Table 2). These predictors each accounted for comparable amounts of unique variance in performance (3.9%–5.1%), and

**Table 1.** *Correlation Matrix and Descriptive Statistics*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Total course performance | — | | | | | | | | | | | | | |
| 2. SAT score | .36*** | — | | | | | | | | | | | | |
| 3. Academic self-efficacy | .27** | .25** | — | | | | | | | | | | | |
| Academic interest speech | | | | | | | | | | | | | | |
| 4. Challenge/threat index | .25** | .03 | .01 | — | | | | | | | | | | |
| 5. CO | .25** | − .01 | .07 | .96*** | — | | | | | | | | | |
| 6. TPR | − .22* | − .07 | .05 | − .96*** | − .83** | — | | | | | | | | |
| 7. HR | − .01 | − .05 | .15 | .04 | .12 | .05 | — | | | | | | | |
| 8. PEP | − .15 | .11 | − .08 | − .28** | − .33*** | .21* | − .60*** | — | | | | | | |
| Test-taking speech | | | | | | | | | | | | | | |
| 9. Challenge/threat index | .16 | .03 | − .04 | .80*** | .77*** | − .75*** | − .05 | − .23* | — | | | | | |
| 10. CO | .18 | − .03 | .00 | .77*** | .80*** | − .67*** | .02 | − .29** | .96 | — | | | | |
| 11. TPR | − .12 | − .08 | .07 | − .75*** | − .67*** | .76*** | .11 | .14 | − .17 | − .83*** | — | | | |
| 12. HR | .00 | .00 | .05 | − .07 | .01 | .15 | .68*** | − .33*** | − .16 | − .07 | .25** | — | | |
| 13. PEP | − .09 | .13 | .01 | − .12 | − .18 | .05 | − .38*** | .63*** | .11 | − .27** | .03 | − .58*** | — | |
| 14. Included in final sample | .10 | .00 | − .04 | .12 | .13 | − .10 | .08 | − .16 | .11 | .11 | − .09 | .18 | − .14 | — |
| Mean | 110.54 | 1207.65 | 44.38 | 0.00 | − 0.25 | 32.03 | 13.47 | − 5.82 | 0.00 | − 0.20 | 31.25 | 13.81 | − 5.32 | 0.70 |
| *SD* | 13.42 | 123.58 | 5.13 | 1.91 | 1.15 | 116.81 | 8.70 | 7.95 | 1.91 | 1.19 | 136.75 | 8.61 | 7.17 | 0.46 |
| *N* | 127 | 121 | 130 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 135 |

*Note*: CO: cardiac output; TPR: total peripheral resistance; HR: heart rate; PEP: pre-ejection period. Final sample inclusion status coded as 0 = *excluded*, 1 = *included*. Cases were included in subsequent regression analyses if they were not missing any of the predictor or outcome variables ($N = 95$). Participants had missing data for self-efficacy and course performance if their experimental sessions were terminated before they completed the scale and permission form, respectively.
*$p < .05$, **$p < .01$, ***$p < .001$.

the model as a whole accounted for 22.5% of the variance in course performance.

Finally, to establish the specificity of the challenge/threat index in predicting performance, we repeated the regression analysis, separately substituting HR, PEP, and an index of the two (HR z-score–PEP z-score) for the challenge/threat index. No effects for these predictors approached significance ($ps > .5$). Furthermore, the effect for the challenge/threat index was unchanged when any of these variables were included simultaneously in the model with it.

## Discussion

As hypothesized, the TPR/CO index from the academic interests speech was associated with performance such that a pattern consistent with relative challenge prospectively predicted a higher point total in the course at the end of the academic term. The cardiovascular markers contributed independently to this prediction, beyond that which could be explained by SAT score and academic self-efficacy. This is an important demonstration for the challenge/threat model because it shows for the first time that

**Table 2.** *Regression Analysis Predicting University Course Performance*

| Variable | *B* | *SE B* | β | $sr^2$ | *P* |
|---|---|---|---|---|---|
| SAT score | 0.025 | 0.010 | .242 | .051 | .017 |
| Academic self-efficacy | 0.558 | 0.247 | .225 | .044 | .026 |
| Academic interest speech challenge/threat | 2.117 | 0.997 | .323 | .039 | .037 |
| Test-taking speech challenge/threat | − 0.583 | 1.000 | − .089 | .003 | .562 |

*Note*: All predictors were entered simultaneously. $N = 95$, model $R^2 = .225$, $p < .001$.

the cardiovascular markers of challenge/threat are not redundant with plausibly overlapping measures. Importantly, the cardiovascular markers that differentiate challenge from threat (TPR and CO) predicted performance, but reactivity common to both states (HR and PEP) did not.

The fact that cardiovascular markers of challenge/threat related to discussing academic interests but not test taking predicted performance suggests that the former topic revealed a particularly important facet of academic success. The general process of pursuing education at the university level entails identifying one's interests and planning an appropriate program of study. Students who are most comfortable with this—thereby exhibiting cardiovascular reactivity consistent with relative challenge while speaking about it—may also have the characteristics and skills that facilitate performing well in courses. Specifically, they may be more motivated because they are taking classes they are truly interested in. This could contribute to better self-regulation and greater persistence during a course, which have been identified as potentially underlying the relationship between self-efficacy and performance (see Chemers et al., 2001). Such students could also possess greater intelligence, which could have contributed to exhibiting cardiovascular markers of relative challenge in this context, but should also have contributed to SAT score and self-efficacy, thus decreasing the unique relationships between the predictors and performance. The current investigation does not establish mediating mechanisms, so their identification remains a topic for future research.

Our study has several limitations. First, SAT scores relied on participants' self-reports, which possibly suffer from reporting bias. It is unclear, however, how this would be related systematically to cardiovascular reactivity or performance in a way that would color interpretation of challenge/threat findings. Second, the predictors assessed general rather than course-specific aspects of academic performance. Measures that are targeted more specifically may function differently. Individually, they may be associated more strongly with performance, but the implications for their unique contributions are less clear. This issue may be particularly relevant for why the test-taking speech did not predict performance significantly. Challenge/threat responses to test taking may be heavily dependent on the subject matter in question, which would require a specifically focused speech topic.

Finally, this study suggests that cardiovascular markers of challenge/threat and physiological measures more generally may reveal important predictors of academic performance that are not accessible with other measures. Establishing this requires additional research (e.g., assessment of other nonphysiological predictors), but because physiological measures typically do not rely on individuals' conscious attention and are not subject to conscious control, they may be more sensitive to some influences on performance than other measures. Incorporating psychophysiology has the potential to enhance understanding of academic goal pursuit, which in turn may provide avenues for improving student performance. For example, using a multimethod approach, it may be possible to identify who is likely to succeed in future coursework as well as who could benefit from remedial assistance and in what areas, such as identifying academic interests and developing study skills.

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