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An Entity Theory of Intelligence Predicts Higher Cortisol Levels When High School Grades Are Declining

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Abstract

Grades often decline during the high school transition, creating stress. The present research integrates the biopsychosocial model of challenge and threat with the implicit theories model to understand who shows maladaptive stress responses. A diary study measured declines in grades in the first few months of high school, salivary cortisol (N=360 students, N= 3,045 observations) and daily stress appraisals (N=499 students, N= 3,854 observations). Students who reported an entity theory of intelligence (i.e. the belief that intelligence is fixed) showed higher cortisol when grades were declining. Moreover, daily academic stressors showed a different, lingering effect on the next day's cortisol for those with different implicit theories. Findings support a process model through which beliefs affect biological stress responses during difficult adolescent transitions.

Keywords

adolescence; stress; threat appraisal; cortisol; biopsychosocial; achievement

For many young people, the transition to high school can seem like the start of a stressful, seemingly-endless marathon (Pope, 2001; Pope, Brown, & Miles, 2013). Students must perform in a new and uncertain academic environment and forge new relationships with teachers and peers, all while keeping an eye on postsecondary opportunities. It is therefore not surprising that grades typically decline during the transition to high school (Benner, 2011; Benner & Graham, 2009; Isakson & Jarvis, 1999). The present research seeks to understand why some students are resilient during this life transition, while others are likely

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to appraise the demands posed by the transition to high school as "too much to handle," resulting in maladaptive psychobiological stress responses.

Our research begins with the intuition that academic stressors, such as struggling to keep up with the rigor of high school classes, are more threatening to students who believe that these struggles are signs that one does not have what it takes to be successful. We test this intuition by integrating a stress response model prominent in affective science—the *biopsychosocial (BPS) model* of challenge and threat (Blascovich, Mendes, Hunter, & Salomon, 1999; Jamieson, Mendes, & Nock, 2013)—with an established model of adolescents' coping with difficulties—*implicit theories of intelligence* (Blackwell, Trzesniewski, & Dweck, 2007; Dweck, Chiu, & Hong, 1995; Yeager & Dweck, 2012). Our study seeks to better understand individual differences in threat-type responses to the demanding academic transition to high school.

The Biopsychosocial Model of Challenge and Threat

In the biopsychosocial model of challenge and threat, appraisals of *demands* (i.e., what one needs to deal with, such as perceptions of uncertainty, danger, and required effort) and *resources* (i.e., what one has at one's disposal to meet the demands, including perceptions of familiarity, knowledge, skills/ability, dispositional factors, and social support) interact to elicit responses to stressors (Blascovich et al., 1999; Jamieson, Hangen, Lee, & Yeager, 2017). On one end of a continuum, *threat* responses manifest when perceived demands are appraised as exceeding resources. On the other end of a continuum, *challenge* responses result when individuals appraise that they have sufficient resources to meet demands.

Challenge and threat appraisals are associated with specific patterns of physiological responding derived from activation of the sympathetic-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axes (see Mendes & Park, 2014 for a review). Both challenge and threat are accompanied by SAM activation, but threat, relative to challenge, more strongly activates the HPA axis (Jamieson et al., 2013). Activation of the HPA axis triggers corticotrophin releasing hormone (CRH), which causes the pituitary gland to release adrenocorticotropic (ACTH) hormone. ACTH then stimulates the release of cortisol from the adrenal glands. Thus, cortisol is an end-product of threat-type stress responses. After release, cortisol exhibits a relatively long half-life (1+ hr). That is, cortisol lingers after stress offset. When the HPA-axis is activated for a prolonged period, this can increase wear and tear on the body's stress systems, which predicts many negative health outcomes (McEwen, 2006; McEwen & Stellar, 1993; Miller, Chen, & Zhou, 2007). From the perspective of the biopsychosocial model, then, it is important to understand what underlies threat-type appraisals of stressors.

Implicit Theories of Intelligence

Situation-specific stress appraisals do not operate in psychological isolation, but occur within the backdrop of general belief systems (see Crum, Salovey, & Achor, 2013; Yeager, Lee, & Jamieson, 2016). The current research posits that individuals are likely to appraise intellectually demanding situations as more threatening when they believe that intelligence is fixed and cannot be developed—i.e., when they hold more of an *entity theory of intelligence* (Blackwell et al., 2007; Dweck et al., 1995). We tested the hypothesis that adolescents' entity theory of intelligence is associated with threat appraisals, and therefore greater cortisol responses to academic stressors.

Students who hold more of an entity theory of intelligence might attribute an academic struggle to a lack of ability (Blackwell et al., 2007; Hong, Chiu, Dweck, Lin, & Wan, 1999). If this occurs, the adolescent may feel that academic difficulties cannot be overcome, and demand appraisals can exceed perceived coping resources. During an academically-challenging period, such as the transition to high school, an entity theory should be associated with the tendency to make threat-type appraisals, resulting in increased HPA-axis activation (e.g., cortisol secretion). On the other hand, for adolescents endorsing more of an *incremental theory of intelligence*—the belief that intelligence can be developed—academic difficulties may seem like setbacks that can be overcome through social support, personal effort, and opportunities for growth (Blackwell et al., 2007; Good, Aronson, & Inzlicht, 2003). High school students endorsing an incremental theory of intelligence should therefore make fewer threat appraisals, report less negative stress, and show lower cortisol levels.

Some recent research in the domain of social-relational stressors supports the plausibility of the present integration of the biopsychosocial and implicit theories models of coping. In one study (Yeager, Lee, et al., 2016, Study 1), implicit theories of *personality*—theories about whether social and moral characteristics are fixed and cannot be developed—were related to high school students' threat appraisals (i.e., ratio of perceived demand to perceived resources) and HPA-axis activation (i.e. cortisol levels) following a controlled social stressor (the Trier Social Stress Test; Kirschbaum, Pirke, & Hellhammer, 1993). These findings were replicated in a sample of adolescents with elevated internalizing symptoms (Schleider & Weisz, 2016), and in a daily diary and cortisol sampling study (Yeager, Lee, et al., 2016, Study 2). However, to date, no empirical research has examined associations between implicit theories of *intelligence*, naturalistic *academic* stressors in high school, and HPA-axis activation. Nor has research leveraged within-person, day-to-day variabilities to understand the relation between implicit theories and lingering effects of academic stressors on prolonged cortisol responses.

Contributions of the Present Research

We conducted two field studies that assessed academic stressors and salivary cortisol levels over multiple days, in an early-high-school student sample. Our hypotheses and analyses addressed three gaps in the literature.

First, implicit theories of intelligence are known to predict a variety of coping responses, including individuals' goals of developing versus demonstrating intelligence (Blackwell et al., 2007), their causal attributions (Hong et al., 1999), their negative self-relevant affect (Robins & Pals, 2002), their neural responses to mistakes (Moser, Schroder, Heeter, Moran, & Lee, 2011; Schroder, Moran, Donnellan, & Moser, 2014), and their changes in academic performance trajectories during difficult school transitions (Blackwell et al., 2007).

Implicit theories of intelligence research, however, has not examined naturalistic physiological responses to academic stressors, perhaps because the situation-specificity of the theory makes it difficult to test predictions about implicit theories and stress physiology in the real world. That is, an entity theory predicts avoidance of stressful situations (Hong et al., 1999), which can reduce stress prevalence, but lead individuals to miss opportunities for intellectual growth and goal advancement (Jamieson, Crum, Goyer, Marotta, & Akinola, 2018). The timing of the present research, however, minimized such situation-selection bias by collecting data during the first few months of high school, before students with an entity theory would have much of an opportunity to take steps or develop strategies to avoid stress, for example, by dropping out of their harder classes.

Second, past research grounded in the biopsychosocial model of challenge and threat has most frequently studied *situation-specific* or acute stress processes in targeted motivated-performance situations (e.g., classroom mathematics exams; Jamieson, Peters, Greenwood, & Altose, 2016; John-Henderson, Rheinschmidt, & Mendoza-Denton, 2015). However, less research has examined whether *situation-general* belief systems, such as implicit theories of intelligence can differentially predict appraisals and physiological responses (for exceptions, see Chen, Langer, Raphaelson, & Matthews, 2004; Crum et al., 2013).

Finally, much of the developmental research on stress has focused on chronic, environmental factors that are not easily modifiable, such as childhood adversity or poverty (Evans & English, 2002), or social identities such as race or gender (Kiang, Yip, Gonzales-Backen, Witkow, & Fuligni, 2006). Our research into associations between belief systems and stress responses may identify factors that could be modified and lead to improvements in stress responses and coping.

Overview of the Present Research

The present research leveraged between-person (Part 1) and within-person (Part 2) variability in academic stressors to understand how and when implicit theories of intelligence predicted cortisol levels in the transition to high school. Secondary dependent measures were self-reported daily negative stress, threat appraisals, and reports of negative intelligence attributions (feeling "not smart").

In Part 1, the global academic stressor was operationalized as a decline in grades from the beginning of ninth-grade to when the saliva samples were collected (~ 12 weeks into the term). Our approach builds on previous research that examined how implicit theories shape students' self-reported coping responses while undergoing a decline in grades (Blackwell et al., 2007), and a meta-analysis showing that implicit theories predict coping more strongly when individuals are undergoing threats to their intelligence (Burnette, O'Boyle, VanEpps, Pollack, & Finkel, 2013). Exploratory analyses of daily diary reports tested whether declining grades were in fact experienced as more intense stressors for those with more of an entity theory, as expected, and whether this explained the relations of implicit theories and grades declines with cortisol.

In Part 2, we explored within-person variability in students' daily reports of academic stressors. This within-person analysis examined whether students' *entity* versus *incremental theory of intelligence* might moderate the link between the previous day's academic stressors and the next day's cortisol response. If adolescents with more of an entity theory and declining grades were more likely to report daily academic stressors, and if those stressors had a lingering effect on cortisol that differed by implicit theories, this could provide micro-level evidence for the processes documented in the Part 1 findings.

Method

Participants

Data were collected from two large public high schools in central Texas (total N=499). School 1 was a large, comprehensive suburban public high school in central Texas (Sample with self-reports N=327; Sample with cortisol data N=202), and School 2 was a large, comprehensive urban public high school in central Texas (self-reports and cortisol N=172). Ninth-grade students (M_{age}= 14.2, SD_{age}= 0.5) during the 2013-2014 school year (School 1), or the 2016-2017 school year (in School 2) were invited to participate. First-year students in high school were recruited because we expected that high school would be a difficult transition with increasing academic demands (Benner, 2011).

According to district records, 52 percent were girls, 54.5% identified as white/European-American, 33.7% Hispanic/Latino/a, 3.9% black/African-American, 2.9% Asian/Asian-American, 3.5% multi-race/ethnicity, and 1.4% other race/ethnicity; 13.6% were eligible for a free or reduced-price lunch program, indicating low family socioeconomic background. Based on students' self-reports, 31% reported two parents or legal guardians graduated from a 4-year college or above, 28% had one of their parents who graduated from a 4- year college, and 23% said neither had a college degree. See online supplement Table S1 for demographic makeup broken out by school.

All data were collected in close collaboration with the school districts. Research protocols were approved by the institutional research review board at the authors' institutions, by the research committee at the participating school districts, and by the collaborating school principals. There were different consent processes, and therefore different response rates, for the data sources. For salivary hormone sampling, a total of N=374 provided parental consent, student assent, and saliva samples. For the daily survey, data were collected from N=499 who provided parental consent and child assent, and who were not absent on data collection days. Because data were collected in a school setting, no pre-screening for illnesses or abnormalities relevant to HPA-axis functioning was implemented. Degrees of freedom varied across analyses due to different patterns of missing data for the various measures (see supplementary analyses online).

Procedure

The study was conducted during the first semester of high school, when academic pressures, one's place in the intellectual hierarchy, and evaluative stressors are presumed to be common (Benner, 2011). A ~30-minute pre-diary survey assessed individual differences, including implicit theories. Later, participants completed ~10-minute daily surveys assessing negative stress and appraisals in their regular academic classes. In School 1, daily surveys and saliva samples occurred Monday, the day before the comprehensive survey, and then Monday through Friday the week after the comprehensive survey (six total days). In School 2, the first saliva assessment was the day of the comprehensive survey session—either a Monday or Tuesday, depending on class schedules. Then, four weeks later, participants in School 2 completed a brief daily check-in survey with saliva sampling over 10 days, Monday through Friday (11 total days). Both School 1 and 2's daily diary and saliva samples occurred at roughly the same point in the first year of high school (between Oct 11 and Nov 11).

Different analyses using the School 1 dataset were reported previously in a randomized trial (Yeager, Lee, et al., 2016) and were posted online (osf.io/9ack7); data from School 2 have not yet been published. Using the School 1 dataset, Yeager, Lee, et al. (2016) examined the effects of a treatment teaching an *incremental theory of personality*—the idea that people's personalities and social traits can change—on students' coping with daily social stressors. The incremental theory of personality treatment was orthogonal to the present study for three reasons. First, here we focused on an individual difference that was assessed prior to random assignment to intervention condition. Hence implicit theories of intelligence did not differ across conditions, even when they were re-assessed after the personality intervention. Second, implicit theories are often domain-specific (Schroder, Dawood, Yalch, Donnellan, & Moser, 2016) and more strongly predict coping within the same domain (e.g., intelligence theories predicting coping with intellectual stressors), but not across domains (e.g., intelligence theories predicting coping with peer relationship stressors). We did not expect interactions of the treatment with the measured implicit theories of intelligence. Indeed, we tested whether the intervention condition reported in Yeager, Lee, et al. (2016, Study 2) interacted with any of the focal variables reported here, and found that it did not. Including an interaction with the incremental theory of personality condition did not change the significance of any of our findings.

Salivary collection.—Salivary cortisol collection, preparation, and analysis followed well-established procedures (c.f., Kirschbaum & Hellhammer, 1994). Procedures were designed to maximize sample size and reduce respondent burden, and keep effects of diurnal rhythm on salivary cortisol relatively constant within participants. We collected one sample per day, but at approximately the same time of day for each participant (Liening, Stanton, Saini, & Schultheiss, 2010). In School 1, samples were collected between 8 a.m. ~ 4 p.m., and in School 2, students provided a sample between 1 p.m. ~ 4:30 p.m. to reduce variability. Time of sample collection was automatically recorded in an electronic daily intake questionnaire, and controlled for in analyses as a proxy for time since waking. Students were asked to refrain from: eating dairy products (i.e., yogurt); drinking caffeinated beverage (i.e., coffee, soda, tea, and energy drinks); taking non-prescribed medications; and engaging in strenuous physical exercise at least two hours prior to sample collection (Adam & Kumari, 2009).

On the day of the salivary cortisol collection, research assistants placed a 2.5ml or 4.0mL Salicap (IBL International, Hamburg, Germany), along with a straw and napkin, at students' desks. Participants provided samples of at least 1.5ml using passive drool procedures (see also Yeager, Lee, et al., 2016). As soon as salivary sample collection was complete, samples were transferred for storage. In School 1 they were transferred to a laboratory freezer located on-site in the school at −20°C. In School 2 samples were transferred immediately to a Yeti™ cooler (Austin, TX) at < 0°C, and at the end of the day stored in a −80°C laboratory freezer. Research staff verified all sample IDs and prepped samples for shipment to be assayed off-site. The daily participation rate remained high across days (mean 87%, min 77%, max 92%). See online supplement for more detail.

After the salivary sample collection, participants completed a brief intake survey about their eating, drinking, exercise, medicine intake, and sleep-wake patterns of the day. Female participants reported on additional questions to examine their menstrual cycles. Adding variables indicating these behaviors or circumstances did not change the primary results, and were not discussed further.

Cortisol assay.—Saliva samples were packed in dry ice or icepacks and shipped to the biological health psychology laboratory at Brandeis University, Waltham, MA (PIs, Nicolas Rohleder and Jutta Wolf; School 1), or assayed in the social neuroendocrinology laboratory at University of Texas at Austin (PI, Robert A. Josephs; School 2). Salivary cortisol was assayed using luminescence immunoassay (CLIA; IBL International, Hamburg, Germany, School 1 and partially for School 2) and enzyme immunoassay (DRG International, Springfield, NJ, USA, School 2). Samples were pipetted either by a Hamilton Company liquid handling robot, or by carefully trained and supervised personnel. All samples were measured in duplicate, and samples with a coefficient of variation (CV) > 10% were repeated. The cortisol assay had a sensitivity of 0.138 nmol/l, with intra- and inter-assay coefficient of variation of 4.64 ~ 9.28% and 5.6 ~ 15.5% respectively.

Measures

Implicit theories of intelligence.—Standard items assessed implicit theories of intelligence (Blackwell et al., 2007; Dweck et al., 1995). In School 1, six items were used; in School 2, four items were administered due to space limitations. Items include "*You can learn new things, but you can't really change your basic intelligence*", "*You have a certain amount of intelligence, and you really can't do much to change it*" (1= *Strongly disagree;* 6 = *Strongly agree*). Responses were averaged (α = .84). Higher composite scores correspond to an entity theory of intelligence.

Global academic stressor: Decline in grades.—Students in these schools received grade reports every six weeks. The between-person global academic stressor was indexed by the amount of change in official academic grades (on a 0-4.3 grade point scale) in core classes (math, English, science, social studies) from the first to second marking period. Daily surveys were administered just before or after the end of the second grading period and corresponded to students' most recent performance feedback. The global academic stressor measure was the difference between grade point averages (GPAs) for core classes in grading period 1 (6^{th} week of the fall semester) and grading period 2 (12^{th} week of the fall semester). Scores greater than zero corresponded to grade increases, whereas scores below zero indicated grade declines. As expected (Benner & Graham, 2009; Isakson & Jarvis, 1999), a majority of students experienced a decline in grades between the first two marking periods in high school (overall 68%; 76% in School 1, and 55% in School 2; quantiles for the grades change score: Min: −1.50, 25th %ile: −0.40, 50th %ile: −0.125, 75th %ile: 0.075, Max: 1.25). Focal analyses centered the grades change variable at the grand mean and then estimated the simple effects at +1*SD* (= +0.19 points, academic improvement between the grading period 1 and 2) and −1*SD* (= −0.57 points, academic declines between the grading period 1 and 2). See the online supplement for the distributions.

Intensity of daily academic stressors.—Students were asked to report up to three negative events that occurred within the past 24 hours and then rated the intensity of the negative events on a scale labeled from *not at all negative* to *extremely negative*. A pair of trained research assistants, blind to hypotheses and implicit theories of intelligence scores, coded open-ended event responses (inter-coder agreement > 90%). Academic events included: receiving a bad grade on exams or homework; failing to pass tests; failing to complete school work before due; falling behind or not understanding lessons taught in class; and any other negative evaluative events in the academic domain. Following the method used in one past study using this dataset (Yeager, Lee, et al., 2016, Study 2), when students did not report any academic events, they were given a value of 1, meaning that they had a *not at all negative* day, in order to avoid dropping data, which could induce bias (see a discussion of collider bias in Morgan & Winship, 2014). The intensities of the negative events were averaged to create a composite score (following Yeager, Lee, et al., 2016, Study 2). Higher values reflect more intense academic stressors experienced at a daily level. Analyses focused on the average intensity of academic stressors across all days (the between-person analysis in Part 1), and the within-person variability in daily academic stressors (Part 2). An analysis of ICCs (Intra-class Correlation Coefficients) found that there was sufficient variability within individuals, over time, ICC = 0.39 (or 61% within-person variability).

Cortisol.—The distribution of raw salivary cortisol values was highly skewed, as is typical (joint test of skewness and kurtosis $W = .38$, $p < .001$ in School 1; $W = .32$, $p < .001$ in School 2). To normalize the distribution to meet the assumptions of the linear model, we trimmed the top/bottom 2% of data as outliers (i.e., biologically implausible or abnormal values; such as values greater than 100 nmol/l) within school, separately for the two schools' data (because assays were conducted separately for each school sample). Hence our conclusions are limited to the 96% of observations in the normal range. A ladder-of-powers analysis showed that the optimal transformation for the trimmed data was a square-root, which was executed. For ease of interpretation and comparability to other published research, the final cortisol values were linearly scaled to have the same mean and standard deviation as the raw cortisol data. See Table 1 for descriptive statistics and see online supplement for untransformed versus transformed cortisol data visualizations. An analysis of ICCs found that there was sufficient variability within individuals, over time, ICC = 0.47 (or 53% within-person variability).

Daily negative stress and threat appraisals.—On the daily survey, students indicated overall stress levels and threat appraisals. On each day, students reported daily negative stress levels on a single item: "*Overall, how stressful is your day today in school so far*?" (from *Not at all stressful* to *Extremely stressful*). We called this negative stress because lay conceptions of stress are that it is negative. Next, participants completed a single-item threat appraisal (i.e. demands outweigh resources): "*Overall, how confident are you that you can handle the stresses you experienced today in school so far?*" The scale was reversed, so that higher values indicated greater daily threat appraisals (from *I can handle all of the stress really well* to *I can't handle the stress at all*). In School 1, a 10-point scale was used, and in School 2, a 7-point scale was used (linearly transformed to the 10-point scale). Analyses of ICCs showed that there were sufficient variabilities within individuals for negative stress and threat appraisals, over time, ICC for negative stress = 0.48 (or 52% within-person variability); ICC for threat appraisals = 0.49 (or 51% within-person variability).

Daily negative intelligence attributions.—To add psychological texture to the study, analyses examined a composite of two items: how much participants felt "dumb" and how much they felt "smart" (reverse-scored), indicating attributions of low intelligence, on a 5-point Likert scale (*1* = *Not at all*, *5* = *A great deal*). Higher values reflected more negative intelligence attributions.

Covariates.—Cortisol levels vary due to a number of personal characteristics and situational factors. Therefore, the following covariates were added to the multilevel mixed-effects linear models to address potential confounds and reduce measurement error: At level 1 (the *day* level), as is standard in analyses of hormones, we controlled for day of the week (Mon ~ Fri dummies) and time of day to account for diurnal rhythms (Adam & Kumari, 2009). To select functional form, we plotted time of day against cortisol using a Loess smoothing curve (see online supplement). Following much past research, a step-function best fit the data. We therefore created three continuous variables indicating time of day and included them in the models.

At level 2 (the *person* level), participant sex, self-reported family socioeconomic status, 8th-grade standardized test scores (z-scored at sample mean), and baseline depressive symptoms scores (measured with Children's Depression Inventory (CDI) and CDI-short form; Kovacs, 1992) were entered as covariates. Depressive symptoms were a critical covariate because helplessness, or the "all or nothing thinking" that characterizes it, could plausibly overlap with an entity theory of intelligence and predict elevated cortisol levels, or, on the other hand, more-depressed youth could show blunted cortisol (Burke, Davis, Otte, & Mohr, 2005). The same covariates were used in all models unless a given covariate prevented a model from converging.

The final R syntax for data analysis is posted at osf.io/eqq6m.

Results

Bivariate Associations

As a preliminary analysis, bivariate, person-level associations between all variables of interest are summarized in Table 2. Students' implicit theories of intelligence were not significantly associated with the measures of stressors that we expected to interact with implicit theories: grades change ($r = -.05$, $p > .10$) or with intensity of daily academic stressors ($r = .04$, $p > .10$). Next, students' implicit theories of intelligence were significantly related to self-reported stress responses: daily negative stress ($r = .14$, $p < .01$), threat appraisals ($r = .18$, $p < .001$), and negative intelligence attributions ($r = .24$, $p < .001$); but not associated with salivary cortisol ($r = .04$, $p > .10$). Finally, self-reported daily stress, threat appraisals, and negative intelligence attributions showed significant associations (*rs* = .29 ~ .61, $p < .001$). In sum, the observed associations were consistent with theory and suggest that the data provided a meaningful sample to test hypotheses.

Next, as a preliminary matter, we sought to illustrate the subjective experience of endorsing an entity theory of intelligence, replicating past research (Blackwell et al., 2007). A multilevel mixed-effect model showed that those with more of an entity theory were more likely to say over the week that they felt "not smart," unstandardized $b = .13$, $t = 3.72$, $p = .0002$, standardized $\beta = .12$, even controlling for prior standardized test scores and current grades. Surprisingly, the relation between an entity theory of intelligence and negative intelligence attributions did not depend on grades change, $b = -.03$, $t = -0.79$, $p = .432$, $\beta = -.05$. Those with more of an entity theory of intelligence felt "not smart" on 31% of days (above a scale point of 2), compared to students with an incremental theory, who felt "not smart" on 17% of days, regardless of their objective performance.

Multi-level Modeling Overview

Primary analyses estimated multilevel mixed-effects linear regression models via the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015). Degrees of freedom and *p*-values were estimated using the *lmerTest* package in R (Kuznetsova, Brockhoff, & Christensen, 2015). Daily measurement occasions (level 1) were nested within individuals (level 2). Part 1 examined between-person processes as a function of implicit theories of intelligence and global academic stressors (grades decline). Part 2 explored within-person processes as a function of implicit theories and within-person variabilities in daily academic stressors. We did not detect differences across schools—there were no significant 3-way interactions with the school dummy variable (*P*s > .25, see online supplement). Therefore, our analyses treated school as a level 2 (person-level) covariate. As noted, we reported results for the full sample with all data stacked.

Part 1: Between-Person Effects of Global Academic Stressors on Cortisol

Part 1 involved between-person analyses of differences in average cortisol concentration and self-reported negative stress and threat appraisals as a function of students' measured implicit theories of intelligence and changes in grades. The random intercept model for the cortisol outcome is presented in Equation 1 below:

<u>Level 1 (day level):</u>

$$Y_{tj}\left(Salivary\ cortisol\right) = \beta_{0j} + \sum_{x=1}^{3} \beta_{xj}\left(Time_{xtj}\right) + \sum_{y=4}^{7} \beta_{yj}\left(Day\ of\ the\ week_{ytj}\right) + e_{tj}$$

Level 2 (person level):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\left(Entity\ theory\ of\ intelligence_j\right) + \gamma_{02}\left(Grades\ change_j\right) + \gamma_{03}\left(Entity\ theory_j \times Grades\ change_j\right) + \sum_{k=4}^{9} \gamma_{0k}\left(Covariate_{kj}\right) + u_{0j}$$

The model estimated a random intercept of salivary cortisol levels across days (t) for a particular individual (j), predicted by the between-person Entity theory of intelligence × Grades change interaction, while controlling for day-level (that is, time of day, and day of the week) and k=6 person-level covariates (sex, 8th grade test scores, depressive symptoms, self-reported family socioeconomic status, intervention condition, and school).

Cortisol.—The test of our primary hypothesis was the significance of the γ_{03} parameter. As hypothesized, there was a statistically significant Entity Theory of Intelligence × Grades Change interaction on salivary cortisol levels, $b = -0.66$, $t = -2.71$, $p = .007$, $\beta = -0.16$ (see Model I in Table 3). This interaction is depicted in Figure 1A, and it was independently significant in each of the two schools (see online supplement). A set of supplementary analyses (reported online) found that it was one's *change* in grades—and not one's absolute academic status—that predicted cortisol levels for those endorsing an entity theory of intelligence. This suggests it was the potentially jarring *loss* of grades that was an academic stressor.

To substantively interpret this interaction, we estimated the γ_{01} parameter in a model that centers grades change at −1*SD* (grades change of −.57 points). Doing so tested whether an entity theory predicted greater cortisol among those whose grades were declining. As hypothesized, those with more of an entity theory of intelligence showed significantly higher levels of daily salivary cortisol when grades were declining, $M_{\text{entity}} = 11.65$ nmol/l, $M_{\text{incremental}} = 10.05$ nmol/l, $b = 0.80$, $t = 2.27$, $p = .024$, $\beta = .11$. Next, the implicit theories predictor (i.e. γ_{01} parameter) was not significant when the grades change variable was centered at an improvement in grades (+1*SD*, or a +.19 grade points increase), $M_{\text{entity}} = 9.84$ nmol/l, $M_{\text{incremental}} = 10.91$ nmol/l, $b = -0.53$, $t = -1.67$, $p = .096$, $\beta = -.07$.

Another approach to interpreting the simple effects is to ask: Are students' physiological stress levels more contingent on levels of academic struggle for students with different implicit theories of intelligence? To address this, a random intercept model estimated the γ_{02} parameter in Equation 1—that is, the simple slope of grades change—among those with measured entity theory (+1*SD*) and incremental theory of intelligence (−1*SD*). Grade declines predicted higher cortisol when individuals had more of an entity theory, $M_{\text{grades decline}} = 11.65$ nmol/l, $M_{\text{grades increase}} = 9.84$ nmol/l, $b = -0.90$, $t = -2.60$, $p = .010$, $\beta = -.12$, but not when individuals had more of an incremental theory (−1*SD*), $M_{\text{grades decline}} = 10.05$ nmol/l, $M_{\text{grades increase}} = 10.91$ nmol/l, $b = 0.43$, $t = 1.21$, $p = .228$, $\beta = .05$. The hormonal stress responses of students with an incremental theory of intelligence seemed to be buffered from declining grades—a phenomenon we revisited in the exploratory within-person analyses in Part 2.

Self-reports of negative stress and threat appraisals.—Between-person effects analyses of self-reports of negative stress and threat appraisals were parallel to the cortisol findings. We observed an Entity Theory of Intelligence × Grades Change interaction effect on daily self-reported negative stress, $b = -.16$, $t = -2.01$, $p = .045$, $\beta = -.11$ (see Model II in Table 3). Simple effects analyses showed that when students' grades more steeply declined (−1*SD* below the mean grades change), students with an entity theory of intelligence were more likely to report higher daily negative stress compared to those with an incremental theory, $M_{entity} = 4.17$, $M_{incremental} = 3.58$, $b = .30$, $t = 2.65$, $p = .008$, $\beta = .12$. Again, the effect of implicit theories on daily negative stress was not statistically significant when grades were increasing (at +1*SD* above the mean grades change), $M_{entity} = 3.66$, $M_{incremental} = 3.71$, $b = -.03$, $t = -0.24$, $p = .812$, $\beta = -.01$ (see Figure 1B), similar to meta-analytic findings (Burnett et al. 2013).

Next, analyses showed a significant Entity Theory of Intelligence × Grades Change interaction effect on daily threat appraisals, $b = -.15$, $t = -2.09$, $p = .037$, $\beta = -.11$ (see Model III in Table 3). Simple effects analyses revealed that the effect of entity theory of intelligence on daily threat appraisals was only significant when grades were declining (−1*SD*, $M_{entity} = 3.59$, $M_{incremental} = 3.09$, $b = .25$, $t = 2.57$, $p = .01$, $\beta = .11$), but not when grades were improving (+1 *SD*, $M_{entity} = 3.04$, $M_{incremental} = 3.13$, $b = -.04$, $t = -0.43$, $p = .67$, $\beta = -.02$; see Figure 1C). First-year students in high school who endorsed more of an entity theory of intelligence *and* experienced academic struggles perceived demands of stressors as exceeding their abilities to cope.

Intensity of academic stressors.—When grades were declining, why might students with an entity theory of intelligence show higher levels of cortisol, signaling worse stress responses? One explanation is that the students with an entity theory of intelligence might be more susceptible to perceiving intense academic stressors from their environments. To test this possibility, we estimated a random intercept model in which Entity Theory of Intelligence × Grades Change interaction predicted the average intensity of daily academic stressors aggregated across all days, while controlling for the average intensity of daily social stressors, Entity Theory of Intelligence × Grades Change interaction, $b = -0.12$, $t = -3.65$, $p < .001$, $\beta = -.19$. Simple slope analyses indicated that when grades were declining (−1SD), those with an entity theory of intelligence reported more intense daily academic stressors across days, $b = 0.15$, $t = 3.36$, $p < .001$, $\beta = .14$, relative to their counterparts with an incremental theory. That is, even when those with an incremental theory had grades declining to the same extent, they were less likely to spontaneously write about academic events and rate them as intensely negative. We did not detect an Entity Theory of Intelligence × Grades Change interaction on the average intensity of daily *social* stressors, $p > .50$.

If students' perceptions of academic stressors differed by their grades decline and implicit theories of intelligence, salivary cortisol levels might only go up when students subjectively perceived the current situation as a stressor. As an exploratory analysis to test this prediction, we estimated a random intercept model with a 3-way interaction of Entity Theories of Intelligence × Grades Change × Average Intensity of Daily Academic Stressor predicting levels of cortisol, and found a marginally significant 3-way interaction, $b = -0.46$, $t = 1.86$, *p* = .064, *β* = −.12. Simple effects analyses showed that when students perceived high academic stressors (+1SD), there was a significant 2-way interaction of Entity Theory of Intelligence × Grades Change predicting cortisol levels, *b* = −1.15, *t* = −3.16, *p* = .002, *β* = −.27. In contrast, when students reported low academic stressors (−1SD), the same 2-way interaction of Entity Theory × Grades Change did not predict cortisol levels, *b* = −0.23, *t* = −0.66, *p* = .51, *β* = −.06. See Figure 2 and online supplement, Table S8. These exploratory findings suggest that the objective reality of performance declines in high school may “get under the skin” and activate the HPA-axis when students endorse an entity theory and subjectively perceive it as an intensely negative event.

Robustness analysis: Permutation tests.—Our core findings come from two schools, with data from the second school replicating the first. Nevertheless, it is important to assess the likelihood that an overall pattern of results appeared due to chance. Relying on the logic of a permutation test (Ernst, 2004), we constructed a series of “null” datasets by randomly shuffling the implicit theories variable that, by design, should show no association between implicit theories and stress or threat appraisals. By construction, the significant results in this null dataset are due to chance alone. We repeat this for 1000 iterations and count the % of randomly permuted datasets that show the same pattern as the real data. Results showed that *no* randomly-permuted dataset found significant interactions and simple effects for all three outcomes, unlike the observed data (see online supplement). This simulation suggests that it is not likely that the overall pattern of between-person effects across outcomes was due to chance alone.

Part 2: Exploratory Analyses of Within-Person Effects of Daily Academic Stressors

Did implicit theories also predict the extent biological stress responses linger the day after academic stressors? If so, this could be a means through which implicit theories predict chronic activation of the HPA-axis. In Part 2, then, an exploratory analysis assessed the possibility that students’ implicit theories of intelligence might predict within-person variability in cortisol in response to the previous day’s negative academic stressors (for similar analytic approaches, see Adam, Hawkley, Kudielka, & Cacioppo, 2006; Reis, Sheldon, Gable, Roscoe, & Ryan, 2000). Within-person analyses model a person’s deviation from his or her own mean across multiple days. Hence, we tested whether experiencing a stressor that is more intense than what is typical was associated with deviations from one’s typical cortisol levels the next day, and whether this was different for students with different implicit theories of intelligence.

We estimated a random intercept and slope model in which salivary cortisol levels on a particular day (*t*) for a particular individual (*j*) were predicted by cross-level interactions between the intensity of the previous day’s academic stressors (lagged *t-1*; level 1 predictor) and implicit theories of intelligence (level 2 moderator). The level 1 (day level) predictors were centered at the person-mean, whereas level 2 (person-level) predictors were centered at the grand-mean, as recommended (Adam et al., 2006; Reis et al., 2000). The analytic sample for this lagged model was limited to observations for which there was a cortisol sample for the current day and a survey response on the previous day. We estimated Equation 2 (bolded variables at level-1 are person-mean centered):

Level 1 (day level):

$$\begin{aligned} Y_{tj}(\textit{Daily salivary cortisol}) \\ &= \beta_{0j} \\ &+ \beta_{1j}\left(\textbf{\textit{Intensity of previous day's academic stressors}})_{t-1j}\right) \\ &+ \beta_{2j}\left(\textbf{\textit{Intensity of current day's academic stressors}})_{tj}\right) \\ &+ \sum_{x=1}^{3} \beta_{xj}\left(Time_{xtj}\right) + \sum_{y=4}^{7} \beta_{yj}\left(\textit{Day of the week}_{ytj}\right) + e_{tj} \end{aligned}$$

Level 2 (person level):

$$\beta_{0j} = \gamma_{00} + \sum_{k=1}^{6} \gamma_{0k}\left(Covariate_{kj}\right) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}\left(\textit{Implicit theories of intelligence}_{j}\right) + u_{1j}$$

We tested the significance of the γ_{11} parameter. Note that we did not model all predictors of the intercept because the focus here was on the within-person variability (fully modeling the intercept yielded the same conclusions, see online supplement).

The model found a significant 2-way cross-level interaction of Intensity of the Previous Day's Academic Stressors × Implicit Theories of Intelligence positively predicting the current day's cortisol levels, b = .44, t = 2.83, p = .005, β = .08 (see Table 4, model IV). Removing the current day's intensity of academic stressors from the model (to reduce collinearity) did not change the magnitude or significance of results.

To inspect the direction of the within-person lagged effects more closely, we estimated and plotted the empirical Bayes estimates of the person-specific slope(β_{1j}) and the person intercept(β_{0j}) for each individual j in Figure 3. This revealed a nuance that we did not anticipate, but is sensible in retrospect, as we explain here. Among the students with an entity theory of intelligence (i.e., centering implicit theories at +1 *SD* from the grand mean), the previous day's academic stressors were *not* significantly associated with the next day's cortisol level, b = −0.16, t = −0.57, p = .566, β = −.02 (see the right panel in Figure 3). That is, among those who believe that intelligence cannot be developed, the previous day's intense academic stressors did not show any significant reduction in cortisol levels, but rather remained high the next day.

In contrast, among the students who believed intelligence can be developed (an incremental theory of intelligence), the intensity of the previous day's academic stressors was significantly *negatively* associated with the next day's cortisol levels, b = −1.05, t = −3.14, p = .002, β = −.12 (see the left panel in Figure 3). Thus, for students who held more of an incremental theory of intelligence, cortisol levels were lower after a day that was more stressful for them than usual.

Why might students with an incremental theory of intelligence have shown a reduction in cortisol levels the day after reporting intense academic stressors? One possibility is that those with an incremental theory show a strong HPA-axis response the day of a stressor, but recover more quickly to baseline the next day. This would produce a negative association between the previous day's stressor intensity and the next day's cortisol, and would mirror the stress recovery findings for a laboratory study of implicit theories of personality (Yeager, Lee, et al., 2016, in Study 1). But the model did not find strong associations between same-day academic stressors and cortisol among those with an incremental theory, $b = .23$, $p = .31$. Therefore, if this stress recovery account is true, it may only be happening for a subset of participants or only very weakly.

A second possibility—one that merits further investigation—is that adolescents with an incremental theory respond to an outsized daily stressor by finding resources to help them cope—such as talking with teachers, peers, or parents about how to study more effectively. A demanding academic stressor may become an opportunity to identify where one's resources are not yet adequate. If true, this would align with past laboratory research showing that an incremental theory caused participants undergoing a failure experience to adopt strategies gleaned from successful peers (Nussbaum & Dweck, 2008), or process their mistakes more thoroughly (Moser et al., 2011). The additional resources acquired by those with an incremental theory may have prepared them to deal with on-going demands, reducing HPA-axis responses. We cannot test this definitively because the present study did not measure appraisals of academic resources, but Figure 2 does suggest that students with the lowest cortisol overall were those with an incremental theory of intelligence, intense stressors, and declining grades. Perhaps they learned to cope most effectively.

Daily social stressors.—Confirming the domain-specificity of implicit theories of intelligence (Schroder et al., 2016), we did not find evidence for the Intensity of Previous Day's Social Stressors (lagged t-1) × Implicit Theories of Intelligence interaction on the next day's cortisol levels (see Table 4, model V).

Self-reported outcomes.—In a final exploratory analysis, we found no within-person, lagged effects of the intensity of previous day's academic stressors on self-reports of negative stress, $b = -.03$, $t = -0.63$, $p = .530$, $\beta = -.01$; or threat appraisals, $b = .03$, $t = 0.69$, $p = .492$, $\beta = .02$. See online supplement Table S13. Thus, the effect of implicit theories on global self-reports was only a between-person phenomenon in the present data. Only cortisol showed the relevant within-person moderation effects.

Discussion

What makes the first semester of high school feel more stressful for some adolescents than for others? To answer this question, our study leveraged diary data that captured first-year high school students' naturalistic academic stressors and their psychobiological stress responses. On average, adolescents who viewed their intelligence as a fixed entity (e.g., believing that intellectual abilities cannot change or improve with effort) were more likely to exhibit elevated salivary cortisol levels, compared to those who believe intelligence can improve, when their GPAs declined at the beginning of high school. This same group of students was also more likely to report higher overall negative stress and perceive they did not possess the resources to sufficiently cope with their daily stressors (i.e. threat appraisals). These findings were significant independently in two schools (see the online supplement); thus the primary findings reported in the between-person analysis have already been replicated.

Daily academic stressors may continue to loom large for struggling students who hold an entity theory, perhaps because of what everyday difficulties portend about their long-term intellectual abilities and prospects. A bad grade or an extra homework assignment may not be viewed as a temporary hassle but rather as a more global sign that the stressors that one can't handle are piling up, and that one is fundamentally "not smart." Supporting this, those with more of an entity theory were more susceptible to perceiving intense daily academic stressors when their grades were dropping at the beginning of high school.

In contrast, when students endorsed a belief that intellectual abilities could grow and develop, they were resilient, demonstrated by (1) overall lower levels of cortisol across days (between-person effects in Part 1); and (2) lowered cortisol the day after an intense academic stressor (within-person effects in Part 2). An incremental theory of intelligence therefore acted as a buffer against prolonged HPA-axis activation when adolescents faced academic struggles.

These findings align with emerging evidence in several domains. Recent meta-analytic data observed an association between implicit theories and internalizing psychopathologies (Schleider, Abel, & Weisz, 2015). The research presented here is consistent with this finding because cortisol reactivity to social stressors is a correlate of later psychopathology (Goodyer, Park, Netherton, & Herbert, 2001). Moreover, as noted, our findings are consistent with a meta-analysis showing that implicit theories predict coping primarily when individuals are undergoing an intellectual challenge, but not when people are unchallenged (Burnette et al., 2013). Here, implicit theories of intelligence only predicted circulating cortisol for those with more steeply declining grades, not when grades were holding steady or increasing, and even this two-way interaction was only present among adolescents who, on average, perceived intense academic stressors. Finally, the current findings provide a reassuring conceptual replication of some recent findings (Yeager, Lee, et al., 2016) integrating implicit theories of *personality* model and the biopsychosocial model of challenge and threat, in the sense that situation-general beliefs in academic domain predicted divergent patterns of threat- vs. challenge-type stress responses.

Nonetheless, implicit theories only modulated within-person stress responses when examining hormonal markers. Perhaps self-reports are less sensitive to daily fluctuations in stressors, and perhaps moderating effects of implicit theories may only be detected when aggregating across multiple days, as in the between-person analyses. Future studies could continue to investigate multi-dimensional aspects of resources and demands appraisals that might explain individual differences in day-to-day stress reactivity and recovery processes. This might be especially important if, as noted, investigations showed that individuals with an incremental theory problem-solve in a way that causes them to accumulate resources that help them better cope with stressors (Moser et al., 2011; Nussbaum & Dweck, 2008).

Contribution to Adolescent Stress Research

A theoretical contribution of this research has been to continue the integration of two major research traditions—the *implicit theories* model of coping (Blackwell et al., 2007; Dweck, 1999; Dweck et al., 1995; Yeager & Dweck, 2012) and the *biopsychosocial model* of challenge and threat (Blascovich et al., 1999; Jamieson et al., 2018). This is valuable for three reasons.

First, several decades of research have found that implicit theories of intelligence predict students' learning processes and outcomes (Aronson, Fried, & Good, 2002; Blackwell et al., 2007; Burnette et al., 2013; Dweck et al., 1995; Good et al., 2003). However, as noted, implicit theories research has not been linked to HPA-axis activation (as indexed via cortisol). Cortisol, as a biological marker of threat-type stress responses (Dickerson & Kemeny, 2004; Miller et al., 2007), is thought to impair brain functioning crucial for academic performance (Lupien, McEwen, Gunnar, & Heim, 2009). Thus our initial findings warrant future studies into why an entity theory of intelligence predicts worse grades in times of stress.

Second, these findings highlight an important yet understudied area of research in adolescent stress: situation-general belief systems. Distinct from developmental factors (e.g., puberty) or environmental factors (e.g., poverty) that have been relatively well-established as prominent predictors of stress responses, beliefs may underlie situation-specific appraisals, and may be learned through socialization (Haimovitz & Dweck, 2016; Mueller & Dweck, 1998; also see, Crum et al., 2013). Therefore beliefs may offer an intervention target.

Third, our findings are consistent with life course development theories of adolescence (Benner, 2011; Elder, 1998). In a review, Benner (2011) noted that early academic adversity during school transition periods, if not addressed, could contribute to lasting educational gaps, starting from lower school engagement and spiraling through higher dropout rate and lower post-secondary enrollment. Importantly, not all students fall into this cycle. An incremental theory of intelligence may function as a psychological resource that buffers young people undergoing difficult life transitions by making them feel like they have the resources to meet their demands, improving stress responses (also see Yeager, Walton, et al., 2016).

Limitations

There are several limitations to consider when interpreting this research. First, implicit theories of intelligence were not experimentally manipulated. Instead, the study measured students' held implicit theories of intelligence as naturally occurring individual differences. As a result, it is possible that cortisol levels and threat-type stress responses might have contributed to declining grades and an entity theory of intelligence, not the other way around. However, past studies have experimentally manipulated implicit theories of intelligence and have shown predicted changes in behavior and coping (see Yeager et al., 2014; Yeager, Walton, et al., 2016) and cognitive control (Schroder et al., 2014). Further, past studies (Yeager, Lee, et al., 2016) have experimentally manipulated implicit theories of *personality*—a different theory than theories of intelligence—and showed that doing so altered adolescents' cardiovascular and neuroendocrine responses to a social-evaluative stress task in the laboratory. But we do not yet know whether teaching an incremental theory of intelligence intervention could alter HPA-axis responses.

Second, our study collected saliva samples once a day. This could contribute to measurement error. Yet our findings appeared across two independent school samples, so they seem to be robust, at least when using a relatively large sample size (for a hormone study).

Finally, we chose the first few grading periods of the transition to high school because we believed declines in grades during this sensitive transition period would be a prominent stressor. Future studies seeking to replicate and extend the present findings should consider whether there are other periods in high school when this is or is not true. For instance, perhaps declining grades at the end of senior year of high school may not be meaningful since most students are already admitted to college. More generally, the psychological meaning of grades decline could vary because it may be contextually defined. Thus, replications of the present effects in other circumstances or domains may first need to identify a subjectively important and intense stressor.

Conclusion

The present research found that students show more resilient physiological responding to a stressful decline in grades if they believe that intelligence can be developed. This justifies research into the exciting possibility that more students might thrive if schools both titrated the demands students experience (by not giving students more than they could possibly handle), and provided students with the growth-oriented belief that, with the right resources, they could continue to develop their abilities to meet reasonable demands.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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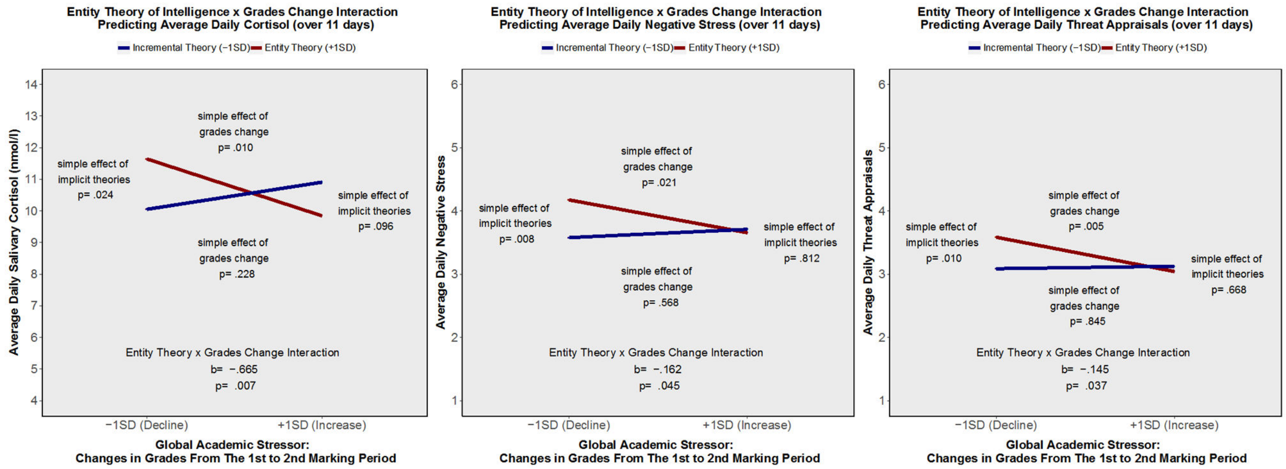

Figure 1. Negative Stress Responses Are Higher For Adolescents With Declining Grades and an Entity Theory of Intelligence (Part 1).

Note: Between-person effects of grades change in ninth-grade on (A) average daily salivary cortisol (nmol/l), (B) average daily negative stress, and (C) average daily threat appraisals over eleven days, moderated by implicit theories of intelligence. Simple effect = Linear effect of one term when the other term in the interaction is centered at + 1SD or −1 SD from the grand mean. Grades decline (−1SD) = 0.57 points decline; Grades increase (+1SD) = 0.19 points increase from the 1st to the 2nd marking period.

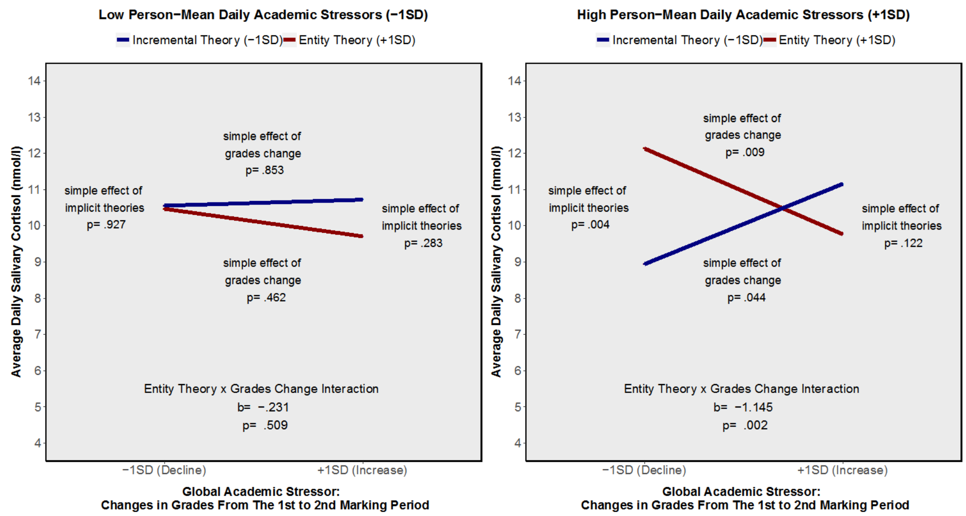

Figure 2. An Entity Theory of Intelligence and Grades Declines Predict Higher Levels of Cortisol Only When Adolescents Perceive More Intense Academic Stressors: An Exploratory Analysis (Part 1).

Note: A random intercept model in R estimated the between-person fixed effects of entity theory of intelligence and grades change on average daily salivary cortisol (nmol/l), moderated by person-average daily academic stressors over 11 days. Simple effect = Linear effect of one term when the other term in the interaction is centered at + 1SD or −1 SD from the grand mean. Grades decline (−1SD) = 0.57 points decline; Grades increase (+1SD) = 0.19 points increase from the 1st to the 2nd marking period.

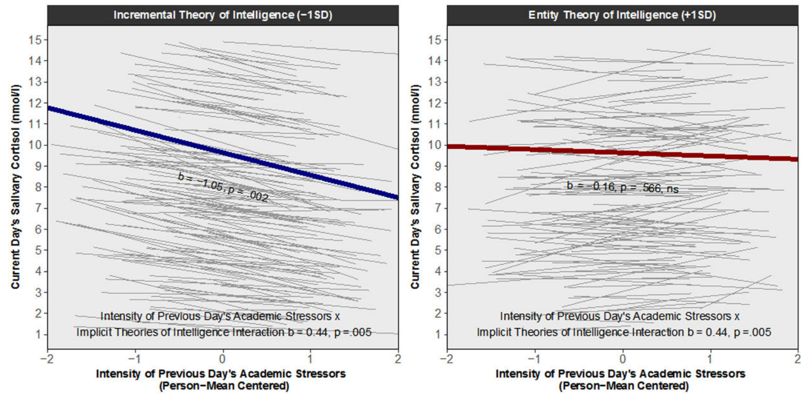

Figure 3. Adolescents With an Incremental Theory of Intelligence Showed Less Lingering Effects From Yesterday's Academic Stressors (Part 2).

Note: An exploratory random slope and intercept model in R estimated within-person associations between the intensity of previous day's academic stressors (level 1, day level predictor) and the current day's salivary cortisol levels (level 1, day level outcome), moderated by implicit theories of intelligence (level 2, person level moderator). Gray lines illustrate person-specific random slopes of the intensity of previous day's academic stressors (*t*-1) predicting the current day's (*t*) salivary cortisol levels. The thicker blue line indicates the group average fixed-effect slope estimated at −1SD (incremental theory of intelligence, left panel), whereas the thicker red line indicates the group average fixed-effect slope estimated at +1SD (entity theory of intelligence, right panel), *b* = unstandardized coefficient.

Table 1.

Descriptive Statistics for Daily Measurements.

	Intensity of Daily Academic Stressors			Cortisol (nmol/l)			Negative Stress			Threat Appraisals			Negative Intelligence Attributions		
	N	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*
All days	3,698	1.93	(1.07)	3,045	7.05	(7.40)	3,853	4.87	(2.57)	3,854	3.86	(2.25)	3,623	1.74	(1.07)
Day 1 (Mon/Tue)	324	2.04	(1.11)	369	8.49	(7.71)	501	5.11	(2.46)	501	4.27	(2.37)	315	2.01	(1.09)
Day 2 (Mon)	513	1.82	(1.05)	351	8.69	(7.46)	511	4.86	(2.47)	510	3.91	(2.25)	502	1.92	(1.11)
Day 3 (Tue)	510	1.96	(1.07)	377	7.98	(6.09)	503	4.65	(2.53)	505	3.94	(2.29)	498	1.86	(1.09)
Day 4 (Wed)	509	1.97	(1.06)	373	7.77	(6.56)	504	4.77	(2.59)	505	3.64	(2.22)	499	1.76	(1.06)
Day 5 (Thu)	507	1.88	(1.06)	371	7.31	(6.62)	503	4.88	(2.63)	502	3.80	(2.31)	492	1.74	(1.01)
Day 6 (Fri)	484	1.85	(1.09)	351	7.72	(7.15)	481	4.41	(2.66)	480	3.52	(2.30)	467	1.72	(1.11)
Day 7 (Mon)	184	2.03	(1.05)	185	5.54	(9.00)	184	5.26	(2.56)	184	3.88	(2.06)	184	1.47	(1.04)
Day 8 (Tue)	170	2.01	(1.09)	171	3.11	(2.45)	170	5.53	(2.62)	170	4.08	(2.15)	170	1.54	(1.03)
Day 9 (Wed)	168	1.86	(1.05)	169	4.77	(13.70)	167	5.52	(2.64)	168	4.02	(1.99)	167	1.40	(0.84)
Day 10 (Thu)	166	2.03	(1.08)	169	5.00	(4.74)	166	4.97	(2.51)	166	3.69	(1.88)	166	1.49	(0.98)
Day 11 (Fri)	163	1.97	(1.12)	159	4.71	(3.69)	163	4.67	(2.50)	163	3.81	(2.13)	163	1.48	(1.07)

Note: *N*= Number of observations. Intensity of daily academic stressors indicate the average intensity (1=*Not at all negative* ~ 4= *Extremely negative*) of up to three negative academic events reported in daily survey. Cortisol (nmol/l) raw means and standard deviations are reported, per day. Missing data occurred due to different consent processes used between self-reports and hormone collection in School 1; and also excused/unexcused absences, conflicts with course schedules or school events for some students, or voluntary withdrawal.

Table 2.

Person-Level Correlations, Means, and Standard Deviations.

Variables	1	2	3	4	5	6	7	*N*	Mean	SD
1. Entity theory of intelligence	–							486	2.57	(1.00)
2. Grades change	−.05	–						486	−0.24	(0.40)
3. Intensity of daily academic stressors	.04	.10*	–					481	1.92	(0.69)
4. Cortisol	.04	−.21***	.00	–				359	8.26	(5.47)
5. Daily negative stress	.14**	.08+	.27***	−.12*	–			486	4.75	(1.91)
6. Daily threat appraisals	.18***	−.05	.10*	.03	.61***	–		486	3.79	(1.71)
7. Daily negative intelligence attributions	.24***	−.18**	.12*	.18***	.29***	.34***	–	481	1.78	(0.82)

Note: Grades change is the changes in average GPAs in core subjects from the 1st to 2nd marking period in 9th grade. Values lower than 0 indicate grades declines, whereas values above 0 correspond with grades increases. Cortisol (nmol/l) values are scaled at raw means and standard deviation after data trimming and transformation.

+ $p < .10$

* $p < .05$

** $p < .01$

*** $p < .001$.

Table 3.

Multilevel Random Intercept Models Testing Between-Person Effects of Grades Change in Ninth-Grade on Daily Salivary Cortisol (nmol/l), Negative Stress, and Threat Appraisals (over 11 days), Moderated by Implicit Theories of Intelligence (Part 1).

	Model I *DV*: Daily Salivary Cortisol (nmol/l)			Model II *DV*: Daily Negative Stress			Model III *DV*: Daily Threat Appraisals		
***IVs*:**	***B* (*SE*)**	**β (*SE*)**	***p***	***B* (*SE*)**	**β (*SE*)**	***p***	***B* (*SE*)**	**β (*SE*)**	***p***
(Intercept)	11.65 (1.74)		< .001 ***	4.17 (0.50)		< .001 ***	3.59 (0.44)		< .001 ***
Level 2 (Person)									
Entity Theory of Intelligence	0.80 (0.35)	0.11 (0.05)	.024 *	0.30 (0.11)	0.12 (0.04)	.008 **	0.25 (0.10)	0.11 (0.04)	.010 *
Grades Change	−0.90 (0.35)	−0.12 (0.04)	.010 *	−0.26 (0.11)	−0.10 (0.04)	.021 *	−0.27 (0.10)	−0.12 (0.04)	.005 **
Entity Theory of Intelligence × Grades Change	−0.66 (0.25)	−0.16 (0.06)	.007 **	−0.16 (0.08)	−0.11 (0.05)	.045 *	−0.15 (0.07)	−0.11 (0.05)	.037 *
Female (vs. Male)	1.91 (0.46)	0.13 (0.03)	< .001 ***	0.27 (0.15)	0.05 (0.03)	.077 +	0.27 (0.13)	0.06 (0.03)	.040 *
Level 1 *N*	2,555			3,371			3,372		
Level 2 *N*	360			486			486		
Residual variance	31.75			3.56			2.74		
Residual standard deviation	5.64			1.89			1.66		

Note: A series of random intercept models in R estimated the between-person effects of Entity Theory of Intelligence × Grades Change interaction on daily salivary cortisol levels (model I), daily self-reported negative stress (model II), and daily threat appraisals (model III), aggregated over 11 days. Entity theory of intelligence was centered at +1SD from the grand mean. The grades change was calculated by subtracting core subjects GPAs in grading period 1 from those in grading period 2, and then centered at −1SD from the grand mean (at 0.57 point decline in GP 2 relative to GP 1) to estimate simple effects of implicit theories when students experience a grades decline. In level 1 (day level) covariates, time of day dummies were added to account for diurnal rhythms; day of the week dummies were compared against Monday. In level 2 (person level) covariates, school 2 was compared against school 1; female (=1) was compared against male (=0). In addition, 8th grade test scores, baseline depressive symptoms, family socioeconomic status, and intervention conditions were entered as level 2 (person level) covariates (see online supplement for the full model output). Degrees of freedom varied due to different patterns of missing data for the various measures. *B* = unstandardized coefficient.

+ $p < .10$

* $p < .05$

** $p < .01$

*** $p < .001$.

Table 4.

Multilevel Random Slope Models Testing Within-Person Lagged Effects of Intensity of Previous Day's Academic Stressors on Current Day's Salivary Cortisol (nmol/l, over 9 days), Moderated by Implicit Theories of Intelligence (Part 2).

	DV: Current Day's Cortisol (nmol/l)					
	Model IV Academic Stressors Only			**Model V Academic and Social Stressors**		
IVs:	***B (SE)***	***β (SE)***	***p***	***B (SE)***	***β (SE)***	***p***
(Intercept)	11.31 (1.89)		<.001 ***	11.23 (1.89)		< .001 ***
Level 1 (Day)						
Intensity of Previous Day's Academic Stressors (*t*-1)	−1.05 (0.33)	−0.12 (0.04)	.002 **	−1.04 (0.34)	−0.12 (0.04)	.002 **
Intensity of Current Day's Academic Stressors (*t*)	−0.01 (0.16)	−0.00 (0.02)	.948	−0.02 (0.16)	−0.00 (0.02)	.904
Intensity of Previous Day's Social Stressors (*t*-1)				0.17 (0.29)	0.02 (0.03)	.550
Cross-Level Interaction						
Intensity of Previous Day's Academic Stressors (*t*-1) × Incremental Theory of Intelligence	0.44 (0.16)	0.08 (0.03)	.005 **	0.45 (0.16)	0.08 (0.03)	.005 **
Intensity of Previous Day's Academic Stressors (*t*-1) × Grades Change	0.22 (0.18)	0.04 (0.03)	.218	0.22 (0.18)	0.04 (0.03)	.226
Intensity of Previous Day's Social Stressors (*t*-1) × Incremental Theory of Intelligence				0.06 (0.14)	0.01 (0.03)	.665
Intensity of Previous Day's Social Stressors (*t*-1) × Grades Change				−0.02 (0.16)	−0.00 (0.03)	.895
Level 1 *N*	1,941			1,941		
Level 2 *N*	354			354		
Residual variance	31.43			31.43		
Residual standard deviation	5.61			5.61		

Note: Random slope and intercept models in R estimated within-person associations between the intensity of previous day's academic stressors and the current day's cortisol levels, moderated by implicit theories of intelligence. Level 1 (day level) predictors were centered at person-level mean; Incremental theory of intelligence was centered at −1SD from the grand mean. Level 1 and 2 covariates were suppressed (see online supplement for the full model outputs). Degrees of freedom varied due to different patterns of missing data for the various measures. *B* = unstandardized coefficient.

** $p < .01$

*** $p < .001$.