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Cortisol reactivity to a teacher's motivating style: the biology of being controlled versus supporting autonomy

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Abstract We hypothesized that participants engaged in a learning activity would show a biological stress response when exposed to a controlling teacher but biological calm when exposed to an autonomy-supportive teacher. Seventy-eight undergraduates (53 females, 25 males) engaged in a 20-minute puzzle-solving activity while exposed to a teacher who enacted either a controlling, neutral, or autonomy-supportive motivating style. Salivary cortisol was assessed before, during, and after the learning activity, and a post-experimental questionnaire assessed participants' perceptions of the teacher's motivating style and indices of positive functioning. Manipulated motivating style affected participants' cortisol, as exposure to a controlling style increased cortisol while exposure to an autonomy-supportive style decreased it, relative to exposure to a neutral style. Correlational analyses with the self-report measures showed that cortisol reactivity occurred in response to interpersonal events rather than to psychological appraisals. We conclude that cortisol reactivity is sensitive to a teacher's motivating style and that elevated cortisol signals interpersonal obtrusion and pressure while dampened cortisol signals perspective-taking and support.

Keywords Cortisol · Motivating style · Autonomy support · Controlling

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Introduction

The same learning task might be experienced as an enjoyable endeavor or as a stressful event, depending on a number of circumstances. One tipping point toward either enjoyment or stress is the quality or tone of the teacher's motivating style during that engagement.

Motivating style: autonomy supportive versus controlling

Motivating style refers to the characteristic way that a person attempts to motivate and engage others in learning activities, and it can be conceptualized along a bipolar continuum that extends from a highly controlling through a neural style to one that is a highly autonomy supportive (Deci et al. 1981). A person with a controlling style motivates and engages others by pressuring them into thinking, feeling, or behaving in a specific way, such as when teachers say, "Do it this way—hurry" (Assor et al. 2005; Reeve 2009; Reeve et al. 2004). Its opposite is an autonomy-supportive style (Deci and Ryan 1985) in which a person motivates and engages others by vitalizing their inner motivational resources, such as when teachers say "Here is an opportunity to learn more about yourself" (Assor et al. 2002; Reeve et al. 2004). The quality of one's motivating style predicts not only the other's extent of task enjoyment (Deci et al. 1981; Koestner et al. 1984; Reeve et al. 2003) but also a wide range of outcomes that index a productive learning experience, such as engagement, conceptual learning, and test performance (Reeve 2009; Vansteenkiste et al. 2004a).

Three conditions characterize a motivating style as a controlling one—neglect of the learner's perspective, intrusion, and pressure (Reeve 2009). That is, teachers (or parents, coaches, physicians, workplace managers, etc.) are controlling when they (1) prioritize their own perspective and outcomes to such an extent that they neglect, dismiss, or overrun the learner's perspective and goals; (2) categorically attempt to change the learner's thoughts (goals, opinions), feelings, and behaviors; and (3) apply pressure until the learner changes his or her thoughts, feelings, and behaviors to align with the teacher's prescription. In contrast, the opposite three conditions characterize an autonomy-supportive style—prioritize the learner's perspective, openness to initiative, and support (Reeve 2009). That is, teachers and others are autonomy supportive when they (1) take and adopt the learner's perspective and goals, (2) welcome and encourage the learner's thoughts, feelings, and behaviors into the flow of the learning activity, and (3) support the learner's capacity for self-direction and autonomous self-regulation by vitalizing their inner motivational resources throughout task engagement.

To put oneself into position to enact a controlling motivating style, one first creates a sufficiently large interpersonal power differential between supervisor and supervisee so that the former has a basis of power (i.e., authority, experience, expertise, status, social position) to use so to push and pressure the latter into compliance (e.g., "be quiet and do what you are told"; Bartholomew et al. 2009). The greater the interpersonal power differential between two interactants, the lower the threshold for pressuring others tends to be and the more likely it is for the powerful person to enact a controlling, power-assertive style (Magee et al. 2007). In contrast, those who support autonomy act to minimize the interpersonal power differential between supervisor and supervisee as they value (empower) the latter's perspective, thoughts, feelings, and behaviors. That is, to put oneself into position to enact an autonomy-supportive motivating style, one first embraces the learner's perspective and listens carefully and patiently so to be better able to vitalize the inner resources (e.g., intrinsic motivation, intrinsic goals) that make agentic action possible (Reeve 2009). An often used metaphor to capture these contrasting interpersonal styles is the "origin-pawn" distinction in which controlling supervisors reduce supervisees to impersonal pawns ("a person who is pushed around by others") whereas autonomy-supportive supervisors view supervisees as origins ("a person…seeking his own goals…and originating her own behavior"; deCharms 1976, p. 3).

Cortisol reactivity

The current study was based on the premise that people engaged in a learning activity would show a biological stress response when exposed to a teacher with a controlling motivating style, just as people engaged in the same learning activity would show biological calm when exposed to a teacher with an autonomy-supportive style. To operationally define a biological stress (versus calm) response, we investigated cortisol—the so-called stress hormone. Cortisol is a hormonal product of the reactivity of the limbic-hypothalamic-pituitary-adrenal (LHPA) axis (Stansbury and Gunnar 1994; Susman 2006). In response to stressful events, limbic structures (amygdala, hippocampus) that process aversive events stimulate the hypothalamus to release the corticotrophin-releasing factor that, in turn, stimulates the anterior pituitary gland to increase release of adrenocorticotrphin hormone (ACTH) into the bloodstream which leads the adrenal gland to increase cortisol production and release. Hence, increased cortisol confirms the activation of a stress-induced coping process (Dickerson and Kemeny 2004), as occurs during relationship conflict (Powers et al. 2006) or being interpersonally devalued or rejected (Stroud et al. 2002).

In the present study, we investigated the extent to which cortisol release (i.e., LHPA reactivity) might function as a biological marker of being interpersonally controlled. Specifically, we predicted that, compared to learners exposed to a teacher with a neutral motivating style, learners exposed to a teacher with a controlling style would show elevated cortisol while learners exposed to a teacher with an autonomy-supportive style would show dampened cortisol. In line with past studies on motivating style (e.g., Deci et al. 1981; Reeve and Jang 2006), we also wanted to document that learners exposed to a teacher with a controlling style would show relatively poor functioning during the learning activity while learners exposed to a teacher with an autonomy-supportive style would show relatively positive functioning (compared to learners exposed to a teacher with a neutral style). So, in addition to cortisol reactivity, we assessed learners' psychological needs (autonomy, competence), perceived stress, and extent of behavioral and emotional engagement. Overall, the hypothesis was that learners exposed to a teacher with a controlling style would show increased cortisol but decreased psychological need satisfaction and engagement while learners exposed to a teacher with an autonomy-supportive style would show decreased cortisol and increased psychological need satisfaction and engagement, relative to learners exposed to a teacher with a neutral style.

Method

Participants

Participants were 82 undergraduate students enrolled in an educational psychology course at a large university in the

Midwest. Each participant received a $20 participation fee in exchange for their participation and abstinence from prohibited substances and activities (explained below). To control for diurnal variation in cortisol, all participants were run between 2:00 pm and 6:00 pm. Four participants (2 females, 2 males) unexpectedly solved one of the puzzles during the puzzle-solving session, so data for these participants were deleted (for reasons explained in the Procedure section), leaving a final sample of 78 participants—53 females and 25 males.

Procedure

We ran participants one at a time. Upon arriving at the laboratory, participants were seated at a large rectangular table and randomly assigned into one of three experimental conditions based on the type of teacher motivating style to which they were exposed. The female experimenter said that the purpose of the study was to investigate puzzle-solving strategies and that the participant would work for 20 min on a pair of SOMA puzzles (see Deci et al. 1982; Zuckerman et al. 1978). She added that the participant would be asked to provide a series of three saliva samples.

The timeline for the experimental procedures appears in Fig. 1. The experimental session began with a 10 min period in which the participant completed the consent form, completed a brief pre-experimental questionnaire assessing demographic data, and rested quietly. After this 10 min period, the experimenter collected the baseline saliva sample to assess cortisol. A 5 min period followed in which the experimenter introduced the experimental task by showing the 7 piece SOMA puzzle and a pair of wooden block models of the puzzle solutions. The experimenter explained that the participant would spend 10 min trying to solve the first SOMA puzzle and then another 10 min trying to solve the second puzzle. For the purposes of the present study, we selected two solutions that we knew in advance would required more than 10 min to solve, as we had performance data (*M*s, *SD*s, *Range*s) from a number of past experiments that used a variety of different SOMA solutions. The reason we had participants work on solutions that they did not have sufficient time to complete was a methodological one, as we wanted to rule out the possibility that a participant might solve the puzzle and hence experience cortisol-moderating positive effectance feedback (i.e., stress-reducing coping; Dickerson and Kemeny 2004) that was unrelated to the teacher's motivating style. As mentioned earlier, four participants unexpectedly solved a SOMA solution (2 participants from the neutral style condition, and 2 participants from the autonomy-supportive style condition), so we deleted their data so that we could analyze a sample of participants who had all performed objectively the same—everyone worked on the same puzzles, for the same amount of time (20 min), and with the same outcome of not solving a puzzle.

As the experimenter left the room, she hit the play button on an audiotape recorder and the voiced instructions began. The prepared instructions ran for precisely 20 min. Outside the experimental room, the experimenter kept track of time on a stopwatch, and she re-entered the experimental room after 20 min. Upon entering, she turned off the audiotape and announced that the puzzle-solving phase of the study had come to an end. She then collected the second saliva sample. Next, the experimenter administered the post-experimental questionnaire and debriefed the participant. After the debriefing and precisely 20 min after the puzzle-solving session had ended, the experimenter collected the third and final saliva sample (see Fig. 1) and paid the participation fee.

Salivary cortisol collection and biochemical analysis

Saliva was collected in a stimulated fashion in which participants chewed Trident original flavor sugarless gum to stimulate saliva flow (Dabbs 1991) immediately prior to each of the three saliva collections. Participants drooled through a four-inch plastic straw directly into a 20-ml collection vial until the saliva reached a vertical line drawn on the vial. Once collected, sealed, and numbered, saliva samples were stored at −20°C until packed in dry ice and shipped in accordance with the Centers for Disease Control and Prevention guidelines for the transport of biological specimens to the Immunology Lab in the Medical School at the National Taiwan University in Taiwan for biochemical analysis. Cortisol in saliva is very stable, can be stored frozen for up to two years at −20°C without compromising sample integrity, and is a valid indicator of the free cortisol concentration in the blood.

Upon arrival at the Immunology Lab, samples were electronically inventoried via assigned bar code numbers and an electronic record was kept for each vial. All samples were stored at −70°C in a locked freezer and exposed to only a single freeze thaw cycle prior to testing. On the day of testing, samples were retrieved from ultra cold storage, checked for identification codes, and allowed to thaw. All samples were centrifuged at 3,000 rpm for 10 min to remove mucins, and clear samples were pipetted into appropriate testing wells to screen for potential problems with pH and blood contamination. Any sample testing positive for blood contamination (>1.0 mg/dL blood protein) was excluded from the analysis, and samples testing outside the acceptable pH range of pH 4-9 were diluted to correct pH prior to testing for cortisol. All samples were divided into pairs and separately assayed in duplicate with a highly sensitive enzyme immunoassay. To reduce sources

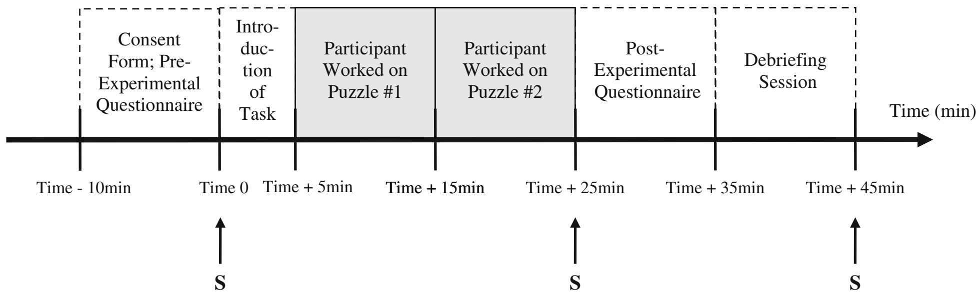

Fig. 1 Timeline for the saliva sampling and prestudy, puzzle-solving, and poststudy procedures. The prestudy task (consent form, pre-experimental questionnaire) lasted 10 min; the experimental instructions and introduction of the task lasted 5 min; the puzzle-solving session lasted 20 min, as the participant worked on Puzzle #1 until time was called after 10 min and worked on Puzzle #2 until time was called after another 10 min; and the poststudy task (post-experimental questionnaire, debriefing) lasted 20 min. S = Saliva sampling

of variability, we analyzed all six samples from each participant (duplicates of the three samples) in the same assay.

Salivary cortisol was analyzed through high-performance liquid chromatography (HPLC), a chromatographic technique, to separate the mixture of compounds and detect the cortisol level. The test uses only 25 µl of saliva (for singlet determinations), has a lower limit of sensitivity of .007 µg/dl, a range of sensitivity from .007 to 1.2 µg/dl, and average intra-and inter-assay coefficients of variation of 4.13% and 8.89% respectively. Method accuracy, determined by spike recovery, linearity, and serial dilution, were 105% and 95%.

To protect the fidelity of the cortisol measurements, several procedures were taken. During participant recruitment, each interested participant received a sheet of instructions that listed several restrictions for the day of the study, including to abstain from caffeine, smoking, alcohol, illegal drugs, or visiting the dentist. Participants were also required not to eat, drink (except for water), exercise, or brush their teeth during the two hour period prior to their scheduled appointment. These same instructions and restrictions were sent to participants a second time via email the night before their day of participation in the study. Upon arrival at the lab, participants were asked if they had complied with the restrictions or felt ill (e.g., elevated temperature, allergies). If so, participants were asked to reschedule to return at a later date. All participants, however, indicated that they had complied with the restrictions and did not feel ill.

Motivating style manipulation

We used the content of the audiotape to manipulate the teacher's motivating style (i.e., controlling, neutral, or autonomy supportive). We used a prepared audiotape (rather than an actual, interactive teacher) to deliver the experimental manipulation for two reasons. First, the use of the audiotape allowed us to control for all the possible differences that might otherwise emerge between the teacher in the three conditions (e.g., facial expressions, number of words said, eye contact), except for the content of the audiotape. Second, the use of the prepared audiotape eliminated the possibility and potential confound that the learner's behavior (e.g., a request for support) might feedback and alter the teacher's motivating style toward the learner.

During the first minute of each puzzle, the voiced instructions were identical, as they welcomed the participant to the study, introduced the SOMA puzzle, and laid out the script of what was to come over the next 20 min. Motivating style was manipulated by varying the content on the audiotape during minutes 1:00 through 10:00 (puzzle 1) and during minutes 11:00 through 20:00 (puzzle 2). For the content and tone of the controlling motivating style, we borrowed heavily from deCharms' (1976) "origin-pawn" game (see pp. 57–59) and from Reeve's (2009) operational definition of motivating style, which uses the following five acts of instruction to define an autonomy-supportive versus a controlling motivating style: nurtures inner motivational resources vs. relies on outer sources of motivation; relies on informational vs. pressure-inducing language; provides vs. neglects explanatory rationales; displays patience to allow time for self-paced learning vs. displays impatience for students to produce the right answer; and acknowledges and accepts negative affect vs. asserts power to overcome students' complaints and expressions of negative affect.

For the neutral motivating style, the tape was silent during minutes 1:00 through 10:00 and minutes 11:00 through 20:00, except for the transitional statement, "Soon, the tape will go silent until the 10 min of puzzle-solving have ended. At that point, I'll come back on the audiotape to let you know when the session is over" and the conclusion statement, "Okay, that's 10 min. That ends the first (second) puzzle."

The following excerpt presents the narrator's script in the controlling motivating style condition during the second minute: "Your job is to get the right answer—solve the puzzle correctly, solve it completely without any mistakes, and solve it before the 10-minute deadline. To do so, do what I tell you to do. When I say, 'Begin,' start solving the puzzle. Don't begin yet. If you started to work on the puzzle, stop—that is not the right way to do it. That's not what you were told to do. Do it right. Sit up straight and put your hands on the table. Listen carefully to me. Make sure the 7 pieces are in their proper order. I want the 7 pieces in order from left-to-right with #1 on the far left-hand side, then #2, then #3, then #4 in the middle, then #5, then #6, and finally #7 goes on the far right-hand side. Make sure the puzzle pieces are in their proper order. If so, good. If not, fix it. Now you are ready to start. Start." For the next 8 min, the narrator continued with a power-assertive tone and pressure-inducing language.

The following excerpt presents the narrator's script in the autonomy-supportive motivating style condition during the second minute: "Are you ready to begin the first puzzle? It will probably help if your take the puzzle as a challenge. To help, I'll offer some hints here at the beginning. You have probably already noticed that we have numbered each individual puzzle piece. Occasionally, I'll refer to these numbers. One more introductory remark is to say aloud what you are probably already thinking—that the puzzle doesn't look easy. If that is what you are thinking, you are right; it is not easy. As a general strategy, what often works is to just play around with each individual piece, and see how it interlocks with the other pieces. In addition, to get you started on the right foot, it might be helpful to arrange the pieces in order from left-to-right with #1 on the left-hand side and #7 on the right-hand side. When you are ready, you may begin the first puzzle." For the next 8 min, the narrator continued with a supportive tone and perspective-taking language.

Measures

The post-experimental questionnaire assessed seven measures—perception of the narrator's motivating style (one measure to assess controlling, a second to assess autonomy support), perceived autonomy, perceived competence, perceived stress, behavioral engagement, and emotional engagement. Each scale used the same 1–7 bipolar response scale that ranged from "strongly disagree" to "strongly agree."

Perceived motivating style

To assess perceptions of how autonomy-supportive the narrator on the audiotape was, participants completed the 6-item short version of the Learning Climate Questionnaire (LCQ; Williams et al. 1996). The LCQ has been widely used in investigations of autonomy support (Black and Deci 2000; Hardre and Reeve 2003; Jang et al. 2009) and includes items such as "I felt understood by the narrator" and "The narrator conveyed confidence in my ability to do well on the puzzle." To assess students' perceptions of how controlling the narrator was, participants completed the 4-item Controlling Teacher Scale (CTS; Jang et al. 2009). The CTS correlates negatively with measures of perceived autonomy support (Jang et al. 2009) and includes items such as "The narrator tried to control everything I did" and "The narrator put a lot of pressure on me." Both scales showed high internal consistency in the present study: perceived autonomy-supportive, *alpha* = .92, and perceived controlling, *alpha* = .94. Because the two scales were significantly intercorrelated [$r(78) = -.44$, $p < .01$] and because self-determination theory conceptualizes autonomy support and controlling as opposite ends of a single continuum, we standardized the two scales and subtracted the perceived autonomy-supportive style z-score from the perceived controlling z-score to yield a single overall perceived controlling style score ($M = 0.00$, $SD = 1.70$), whereby positive scores indicate a controlling style and negative scores indicate an autonomy-supportive style. While we emphasized the overall score, we also report the two separate scores to evaluate the fidelity of the manipulation check.

Perceived autonomy

We used the Perceived Self-Determination scale (PSD; Reeve et al. 2003) to assess perceived autonomy. The PSD scale includes 10 items to assess an internal perceived locus of causality (3 items, including "I was pursuing goals that were my own.") psychological freedom (3 items, including "During the puzzle-solving, I felt free."), and perceived choice over one's actions (4 items, including "I felt it was my own choice what to do and what not to do."). In past research, the three subscales have intercorrelated highly and the total score has correlated with other measures of perceived autonomy and explained intrinsic motivation outcomes such as self-reported interest and free-choice behavior (Jang et al. 2009; Reeve et al. 2003). The PSD scale displayed adequate internal consistency in the present study (10-items, *alpha* = .90).

Perceived competence and perceived stress

Participants' perceived competence and perceived stress were assessed with the Activity-Feelings States (AFS) scale (Reeve and Sickenius 1994). The AFS scale presents the stem, "During the puzzle-solving activity, I felt…" and lists three items to assess perceived competence (i.e., capable, competent, my skills are improving; *alpha* = .74) and three items to assess perceived pressure (i.e., stressed, pressured, uptight; *alpha* = .80). Scores from the perceived competence scale have been shown to correlate highly with perceived competence scores from the Basic Needs Scale and also to predict educationally-relevant outcomes such as grades, engagement, and intrinsic motivation (Jang et al. 2009). Scores from the perceived pressure scale have been shown to correlate highly with alternative measures of perceived stress, perceived tension, and ego-involvement (Reeve and Sickenius 1994) and are used to serve as an emotional marker of the presence of motivations that are antagonistic to autonomous motivation, such as stress, ego-involvement, and the Zeigarnik effect (see Ryan et al. 1991).

Behavioral and emotional engagement

We assessed the extent of participants' engagement in two ways—behavior and emotion (following Skinner et al. 2009). To assess behavioral engagement, we use a 3-item scale that featured the stem, "While puzzle-solving:" followed by the three items of, "I paid attention"; "I put forth a lot of effort"; and "I tried to learn as much as I could." The items for this scale were taken and slightly adapted from widely-used and previously validated behavioral engagement scales (Miserandino 1996; Skinner et al. 2009; Wellborn 1991), and showed satisfactory internal consistency in the present study, *alpha* = .78. To assess emotional engagement, we used a 4-item scale that featured the stem, "Rate 'Playing with the SOMA puzzle' as an activity:" followed by the four items of, "I enjoyed the experience"; "It was fun"; "It stimulated my curiosity without interruption"; and "It was very interesting." This scale assessed participants' energized emotional states (enjoyment, fun, curiosity, and interest), corresponds closely to the concept of self-reported intrinsic interest, and its items were adapted from Skinner et al. (2009) previously validated scale. The items in the emotional engagement scale showed satisfactory internal consistency in the present study, *alpha* = .83.

Results

Manipulation check

Descriptive statistics showing participants' perceptions of the teacher's (i.e., narrator's) motivating style appear in Table 1. Experimental condition affected how participants rated the teacher, $F(2, 75) = 25.52$, $p < .01$. As evaluated by Student–Newman–Keuls post hoc mean comparisons, participants rated the narrator in the controlling condition as significantly more controlling than did participants in the neutral condition who, in turn, rated the narrator as significantly more controlling than did participants in the autonomy-supportive condition. Broken down separately by controlling and autonomy-supportive scores, participants rated the narrator in the controlling condition as significantly more controlling than did participants in either the neutral or autonomy-supportive conditions, $F(2, 75) = 47.68$, $p < .01$, and participants rated the narrator in the autonomy-supportive condition as significantly more autonomy supportive than did participants in either the neutral or controlling conditions, $F(2, 75) = 11.26$, $p < .01$. Within condition, participants rated the narrator in the controlling condition as moderately controlling and as not at all autonomy supportive (*M*s, 5.29 and 2.47, respectively on the 1–7 scale). In the neutral motivating condition, participants rated the narrator as neither controlling nor autonomy supportive (*M*s, 2.33 and 2.41). In the autonomy-supportive condition, participants rated the narrator as not at all controlling and as moderately autonomy supportive (*M*s 1.97 and 4.02).

Table 1 Descriptive statistics for perceived teacher motivating style by experimental condition

	Experimental condition		
	Autonomy-supportive motivating style ($n = 23$)	Neutral motivating style ($n = 25$)	Controlling motivating style ($n = 30$)
Overall perceived			
Controlling *M*	-1.31_a	-0.13_b	$+1.27_c$
Motivating style (*SD*)	(0.88)	(1.25)	(1.61)
Perceived			
Autonomy-supportive *M*	4.02_a	2.41_b	2.47_b
Motivating style (*SD*)	(1.22)	(1.40)	(1.37)
Perceived			
Controlling *M*	1.97_a	2.23_a	5.29_b
Motivating style (*SD*)	(0.80)	(1.45)	(1.69)

Possible range, 1–7, except for overall perceived controlling motivating style which is expressed as a *z*-score (actual *range*, −3.08 to 3.10), with positive numbers indicating a relatively controlling style and negative numbers indicating a relatively autonomy-supportive style. Means with different subscripts differ from one another, $p < .05$, according to Student–Newman–Keuls post hoc mean comparisons

Cortisol

Preliminary analyses showed that baseline cortisol concentrations did not differ as a function of the time of day (Noon, 1 pm, 2 pm, 3 pm) in which participants were individually tested (Ms, 6.8 ± 0.5 for noon, 6.3 ± 0.5 for 1:00, 6.7 ± 0.6 for 2:00, 7.0 ± 1.0 for 3:00), $F(3, 74) < 1$.

Similarly, preliminary analyses showed that baseline cortisol concentrations did not differ as a function of gender (Ms, 6.0 ± 0.5 for males, 6.8 ± 0.3 from females), $t(76) = 1.38$, *ns*. In addition, cortisol concentration levels at time 2 and at time 3 did not vary significantly as a function of either time of day (Fs < 1) or gender (ts < 1). We therefore collapsed the cortisol data across time of day and gender to create a single sample.

No significant differences in baseline cortisol emerged among the three experimental conditions, $F(2, 75) = 2.65$, $p < .08$, though the baseline cortisol of participants in the neutral condition did trend a bit higher than the baseline levels of participants in the other two conditions, a trend we dealt with by employing an ANCOVA analysis. A repeated measures mixed ANCOVA with experimental condition specified as the between-participants factor, time of cortisol assessment as the repeated within-groups factor, and baseline cortisol as the covariate revealed a significant main effect for experimental condition on time 2 cortisol, $F(2, 74) = 17.85$, $p < .01$, $n^2 = .33$. As shown in Fig. 2, cortisol level at time 2 (adjusted for baseline level) increased significantly for participants in the controlling condition compared to participants in the neutral condition

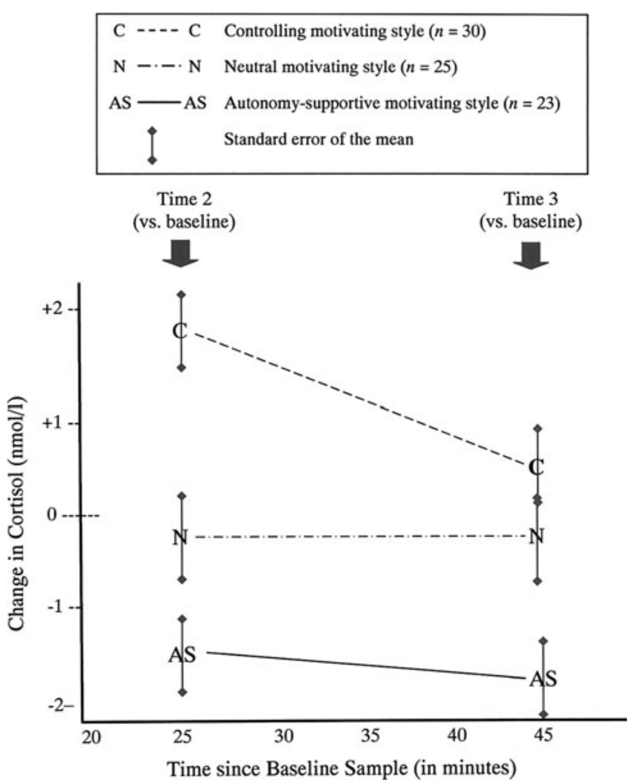

Fig. 2 Changes in cortisol as a function of time since baseline and type of teacher's motivating style. Scores at Time 2 and Time 3 have been adjusted to control for any differences in baseline (Time 1) level of cortisol

(Ms, +1.89 vs. −0.09; $p < .01$), and cortisol level decreased significantly for participants in the autonomy-supportive condition compared to participants in the neutral condition (Ms, −1.47 vs. −0.09; $p < .05$). A second repeated measures mixed ANCOVA revealed a significant main effect for experimental condition on time 3 cortisol, $F(2, 74) = 6.89$, $p < .01$, $n^2 = .16$. As shown in Fig. 2, cortisol level at time 3 (adjusted for baseline level) decreased significantly for participants in the autonomy-supportive condition compared to participants in the neutral condition (Ms, −1.60 vs. −0.10; $p < .05$), though the cortisol levels of participants in the controlling and neutral conditions were not significantly different (Ms, +0.51 vs. −0.10, *ns*).

Considered within condition, for participants in the neutral style condition, cortisol levels remained statistically unchanged over time ($M_{\text{baseline}} = 7.25$, $M_{\text{time 2}} = 7.17$, $M_{\text{time 3}} = 7.09$), $F(1, 24) < 1$. For participants in the autonomy-supportive condition, cortisol levels decreased significantly ($M_{\text{baseline}} = 5.48$, $M_{\text{time 2}} = 4.00$, $M_{\text{time 3}} = 3.97$), $F(1, 22) = 13.43$, $p < .01$. For participants in the controlling style condition, cortisol levels tended to increase ($M_{\text{baseline}} = 6.68$, $M_{\text{time 2}} = 8.57$, $M_{\text{time 3}} = 7.18$), $F(1, 29) = 3.14$, $p < .09$. Importantly, changes in cortisol levels for participants in the controlling condition were characterized by a significant quadratic trend (see Fig. 2), $F(1, 29) = 25.46$, $p < .01$, such that cortisol level increased significantly at time 2 but returned to baseline levels after the 20-minute recovery period (time 3).

A cortisol increase greater than 2.8 nmol/L reflects a cortisol secretory episode (Van Cauter and Refetoff 1985) that defines a clear-cut cortisol response (see also Schommer et al. 2003; Smeets et al. 2006). To supplement this absolute criterion, we added a relative criterion of a > 40% nmol/L increase in cortisol over baseline. Together, we used both the absolute and relative criteria to operationally define the presence of a clear-cut cortisol response. As an example, a participant with a baseline 6.0 nmol/L cortisol level who displayed a 9.0 nmol/L cortisol concentration at time 2 would be classified as showing a clear-cut cortisol response, as the increase of 3.0 nmol/L over baseline would satisfy the absolute criterion while the increase of 50% nmol/L over baseline would satisfy the relative criterion. Further, we applied these same two criteria to operationally define a clear-cut cortisol suppression response. That is, we defined a clear-cut cortisol suppression response by a cortisol drop of >2.8 nmol/L from baseline (absolute criterion) and a > 40% nmol/L drop from baseline (relative criterion). As an example, a participant with a baseline 6.0 nmol/L cortisol level who displayed a 3.0 nmol/L cortisol concentration at time 2 would be classified as showing a clear-cut cortisol suppression response, as the decrease of 3.0 nmol/L from baseline would satisfy the absolute criterion while the decrease of 50% nmol/L from baseline would satisfy the relative criterion.

In the assessment of clear-cut cortisol responses broken down by experimental condition, 0 out of 23 participants (0%) in the autonomy-supportive style condition displayed a clear-cut cortisol response; 0 out of 25 participants (0%) in the neutral style condition displayed a clear-cut cortisol response; while 12 out of 30 participants (40%) in the controlling style condition displayed a clear-cut cortisol response. The effect of experimental condition on the number of clear-cut cortisol secretory episodes was significant, X^2 ($df = 2$, $N = 78$) = 22.69, $p < .001$.

In the assessment of clear-cut cortisol suppression responses broken down by experimental condition, 11 out of 23 participants (48%) in the autonomy-supportive style condition displayed a clear-cut cortisol drop; 2 out of 25 participants (8%) in the neutral style condition displayed a clear-cut cortisol drop; while 0 out of 30 participants (0%) in the controlling style condition displayed a clear-cut cortisol drop. The effect of experimental condition on the number of clear-cut cortisol secretory suppression episodes was significant, X^2 ($df = 2$, $N = 78$) = 23.43, $p < .001$.

Quality of experience

The effects of experimental condition on participants' perceived autonomy, perceived competence, perceived stress, and self-reported behavioral and emotional engagement appear in Table 2. Experimental condition affected perceived autonomy, $F(2, 75) = 27.58$, $p < .01$, as participants in the controlling condition reported significantly lower perceived autonomy than did participants in either the autonomy-supportive or neutral conditions, which did not differ significantly from one another. Experimental condition affected perceived competence, $F(2, 75) = 8.68$, $p < .01$, as participants in the autonomy-supportive condition reported significantly higher perceived competence than did participants in either the neutral or controlling conditions, which did not differ significantly from one another. Experimental condition did not affect perceived stress, $F(2, 75) < 1$. Experimental condition did not affect behavioral engagement, $F(2, 75) < 1$, as participants in all three conditions reported comparably high levels of on-task attention and effort (i.e., *M*s were 5.96, 6.09, and 5.89, respectively, on a 1–7 scale). Experimental condition affected emotional engagement, $F(2, 75) = 4.19$, $p < .02$, as participants in the controlling condition reported significantly lower positive emotionality than did participants in either the autonomy-supportive or neutral conditions, which did not differ significantly from one another.

Intercorrelations among dependent measures

As a supplemental analysis, we computed the zero-order correlations among the dependent measures included in the study. To represent cortisol reactivity, we used change in cortisol at time 2 (time 2 cortisol *minus* baseline cortisol) and change in cortisol at time 3 (time 3 cortisol *minus* baseline cortisol). As shown in Table 3, change in cortisol at time 2 tended to correlate more strongly with the objective social event in the study (experimental condition, or manipulated motivating style; $r = .57$) than it did with participants' psychological experiences of perceived motivating style, perceived autonomy, perceived competence, perceived stress, behavioral engagement, or emotional engagement (*range* of $|r\text{'s}| = .02$ to .44).

The overall pattern of data—as summarized in Tables 1–3 and Fig. 2—was that the changes in cortisol and the quality of experience were driven by the independent variable of manipulated motivating style, as exposure to a teacher with a controlling style elevated cortisol and undermined quality of experience (i.e., psychological need frustration, poor emotionality). The notable exception to this pattern was that exposure to a controlling style did not decrease behavioral engagement (Table 2). To determine if exposure to a teacher with a controlling style affected the *quality* of participants' behavioral engagement, we followed the recommendations and statistical procedures of others (Deci et al. 1994; Joussemet et al. 2004; Ryan et al. 1991; Vansteenkiste et al. 2004b) to examine the within-condition correlations between behavioral engagement and indices of the quality

Table 2 Descriptive statistics for dependent measures by experimental condition

	Experimental condition		
	Autonomy-supportive motivating style ($n = 23$)	Neutral motivating style ($n = 25$)	Controlling motivating style ($n = 30$)
Perceived autonomy *M* (*SD*)	5.06_a (0.94)	5.03_a (0.88)	3.27_b (1.20)
Perceived competence *M* (*SD*)	5.09_a (0.95)	4.20_b (1.10)	3.91_b (1.06)
Perceived stress *M* (*SD*)	3.26 (1.43)	3.34 (1.12)	3.53 (1.57)
Behavioral engagement *M* (*SD*)	5.96 (1.13)	6.09 (0.78)	5.89 (0.80)
Emotional engagement *M* (*SD*)	5.50_a (1.15)	5.36_a (0.86)	4.72_b (1.12)

Possible range, 1–7. Means with different subscripts differ from one another, $p < .05$, according to Student–Newman–Keuls post hoc mean comparisons

Table 3 Descriptive statistics and intercorrelations among all dependent measures

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Experimental condition[b]	–	.57**	.38**	.64**	−.58**	−.42**	.08	−.04	−.30**
2. Δ Cortisol, time 2		–	.61**	.44**	−.42**	−.29*	.02	−.16	−.16
3. Δ Cortisol, time 3			–	.22[a]	−.23*	−.18	.01	−.11	.02
4. Perceived motivating style				–	−.73**	−.51**	.17	−.10	−.38**
5. Perceived autonomy					–	.43**	−.35**	.34**	.56**
6. Perceived competence						–	−.14	.12	−.29**
7. Perceived stress							–	.02	−.14
8. Behavioral engagement								–	.47**
9. Emotional engagement									–
Mean	2.09	0.24	−0.31	0.06	4.36	4.35	3.39	5.97	5.16
Standard deviation	0.83	2.47	2.17	1.68	1.33	1.14	1.39	0.90	1.10
Range	−1 to +1	−7.30 to 4.98	−7.50 to 6.50	−3.08 to 3.10	1.75 to 6.67	1.33 to 7.00	1.00 to 6.50	1.00 to 7.00	1.00 to 7.00

$N = 78$

* $p < .05$

** $p < .01$

[a] $p < .06$

[b] Experimental condition scored as: autonomy support, −1; neutral, 0; and controlling, +1

of experience (autonomy need satisfaction, positive emotionality). Behavioral engagement correlated positively and strongly with both perceived autonomy and emotional engagement for participants in the autonomy-supportive [$r(23) = .51$, $p < .01$, and $r(23) = .69$, $p < .01$, respectively] and neutral [$r(25) = .56$, $p < .01$, and $r(25) = .63$, $p < .01$, respectively] conditions, but not for participants in the controlling condition [$r(30) = .13$, *ns*, and $r(30) = .25$, *ns*, respectively]. Comparatively, behavioral engagement correlated with perceived autonomy more strongly for participants in the autonomy-supportive and neutral conditions than it did for participants in the controlling condition, $r(48) = .53$ vs. $r(30) = .13$, $z = 1.89$, $p < .06$, two-tailed. Similarly, behavioral engagement correlated with emotional engagement more strongly for participants in the autonomy-supportive and neutral conditions than it did for participants in the controlling condition, $r(48) = .66$ vs. $r(30) = .25$, $z = 2.21$, $p < .05$, two-tailed.

Discussion

As expected, participants in the control group showed a mildly positive profile in terms of their task experience (see Table 2)—relatively high perceived autonomy and behavioral engagement, moderate perceived competence and emotional engagement, low perceived stress, and a cortisol level that remained essentially unchanged and unpopulated by secretory episodes. These participants were essentially offered independent free time with an interesting, challenging task. Introducing the teacher with a controlling style significantly changed that experience. These participants showed lower perceived autonomy, lower positive emotionality, and a cortisol level that was both higher and characterized by secretory episodes. Introducing the teacher with an autonomy-supportive style also significantly changed that experience. Participants in the autonomy-supportive condition showed higher perceived competence and a cortisol level that was lower and populated by episodes of cortisol suppression. Overall, the findings confirm the hypothesis that a teacher's motivating style affects learners' cortisol reactivity, with heightened cortisol serving as a biological marker of being controlled and dampened cortisol serving as biological marker of autonomy support.

Cortisol reactivity occurred in response to interpersonal events rather than in response to psychological appraisals. That is, it was the exposure to social intrusion, pressuring-inducing communications, and a relationship that neglected and frustrated the learner's perspective that elevated cortisol, while it was the exposure to social support, origin-fostering communications, and a relationship that encouraged and embraced the learner's perspective that dampened cortisol, rather than changes in psychological experiences such as perceived autonomy, perceived competence, or perceived stress. In regard to the lack of a correlation between cortisol reactivity and perceived stress, past studies have reported this same lack of correspondence between these two measures (Kirschbaum et al. 1995b; Dickerson and Kemeny 2004). Hence, our conclusion is that cortisol rises and falls in reaction to social conditions. That said, we acknowledge that we assessed all of our dependent measures using only explicit (conscious) assessments. It is possible that implicit (unconscious) measures of these same constructs might produce an altered pattern of results (following Schultheiss and Brunstein 2010).

A unique finding in the present study was that participants in the autonomy-supportive condition showed a significant decrease in cortisol—relative to participants in the control group and relative to their own baseline assessment (see Fig. 2). These participants not only showed a decrease in cortisol in the presence of the teacher (time 2) but during the recovery period as well (time 3). In research on social support during acute stress, the presence of social support does dampen the intensity of a cortisol response relative to its absence (Kirschbaum et al. 1995a; Taylor et al. 2010). However, in these studies, people receiving social support still experienced the stressors they faced as cortisol elevating, just less so. In our study, cortisol level actually decreased with autonomy support. We explored the possibility that the significantly higher perceived competence participants in the autonomy-supportive style condition experienced might explain their dampened cortisol, but within-condition correlations showed that perceived competence did not covary with changes in cortisol either at time 2, $r(23) = -.04$, *ns*. or at time 3, $r(23) = .13$, *ns*. Instead, cortisol dampening tracked only their direct exposure to the autonomy-supportive motivating style. It is possible that such dampened cortisol characterizes autonomy support in particular and not social support in general. If so, the implications that this biological calming effect of autonomy support might have for learning, adjustment, performance, and well-being deserve attention in future programs of research.

We designed our study to test the hypothesis that motivating style might cause a change in learners' cortisol levels. We did not, however, design our methodology to adequately pursue the question of what effects such changes in cortisol would then have on learners' post-episode functioning and performance. Now that the present study has confirmed that motivating style causes changes in cortisol, future studies can be tailored to test the consequences of these biological changes, if any.

Generally speaking, cortisol reactivity serves a short-term adaptive function—it mobilizes attention and energy in response to a social-evaluative threat (Dickerson and Kemeny 2004), and it promotes resilience or "physiological toughening" to future stress experiences (Dienstbier 1989). Participants exposed to the controlling teacher did show strong behavioral engagement, as they paid attention, put forth effort, and tried to learn as much as they could. This effortfullness was nevertheless disconnected from their autonomous motivation (perceived autonomy) and positive emotionality. It appeared to be more a form of stress-induced coping—what self-determination theorists refer to as "internally controlled persistence" (Ryan et al. 1991)—rather than a form of volitional engagement.

Longer term, cortical reactivity (repeated LHPA activation) from chronic activation of the stress system takes a cumulative toll on the body, a phenomenon termed "allostatic load" (McEwen 1998). Cortisol-induced allostatic load puts the individual at risk of negative biological outcomes (e.g., diabetes, hypertension), but it has further been linked to maladaptive cognitive outcomes, such as poor memory, impaired problem solving, and poor intellectual functioning in general (Brown and Suppes 1998; Kirschbaum et al. 1996). In the present study, participants exposed to the controlling teacher did show evidence of (cortisol) recovery (see Fig. 2), suggesting only a short-term biological upset in response to the controlling teacher's pressure-inducing style. That said, the question remains as to what the consequences of repeated exposures to a controlling supervisor might be. Studies that have examined cortisol reactivity in response to recurring stressors find that cortisol activation peaks with an initial exposure but continues to show reactivity in subsequent exposures, though to a lesser degree (Kirschbaum et al. 1995b; Schommer et al. 2003). When these studies are combined with the findings from the current study, they call for future research on the long-term consequences of people's chronic exposure to a controlling relationship, climate, or organization.

Overall, the present research on motivating style, cortisol reactivity, and positive functioning opens up three important future research arenas. First, what are the immediate effects of motivating style on cortisol reactivity? Assuming that our findings can be replicated, the present study informs this first topic. Second, what are the long-term effects of motivating style on cortisol reactivity? As to the dampening effect observed for participants in the autonomy-supportive condition, this effect persisted into the 20-minute recovery period so that it is not yet clear how long this dampening effect might last or what its benefits (or costs) might be. As for the effects of that repeated exposure to a controlling style might have, this seems to be a particular important question for future research, as heightened cortisol reactivity seems to be a reliable response to relationship conflict though people sometimes, over time, later show a blunted cortisol response as they dissociate or disengage from the stress-inducing relationship (Davies et al. 2006, 2007; Gunnar and Vazquez 2001; Miller et al. 2007). Third, what are the long-term outcomes associated with chronic or dampened cortisol reactivity? Chronically-elevated cortisol leads to serious long-term deficits, even to hippocampal damage (Cicchetti and Rogosch 2001), but it remains an open question as to the long-term consequences of chronically relaxed cortisol. In setting the stage for these future research questions, we can conclude from the present study that cortisol reactivity is sensitive to a supervisor's motivating style and that elevated cortisol signals interpersonal obtrusion and pressure while dampened cortisol signals perspective-taking and support.

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