The Dark Side of Creativity: Biological Vulnerability and Negative Emotions Lead to Greater Artistic Creativity

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Historical and empirical data have linked artistic creativity to depression and other affective disorders. This study examined how vulnerability to experiencing negative affect, measured with biological products, and intense negative emotions influenced artistic creativity. The authors assessed participants' baseline levels of an adrenal steroid (dehydroepiandrosterone-sulfate, or DHEAS), previously linked to depression, as a measure of affective vulnerability. They then manipulated emotional responses by randomly assigning participants to receive social rejection or social approval or to a nonsocial situation. Participants then completed artistic collages, which were later evaluated by artists. Results confirmed a person-by-situation interaction. Social rejection was associated with greater artistic creativity; however, the interaction between affective vulnerability (lower baseline DHEAS) and condition was significant, suggesting that situational triggers of negative affect were especially influential among those lower in DHEAS, which resulted in the most creative products. These data provide evidence of possible biological and social pathways to artistic creativity.

Keywords: *creativity; social rejection; neuroendocrine; DHEAS; affective vulnerability*

What makes someone creative? Certainly, some individuals are more creative than others. We merely need to compare da Vinci and Monet masterpieces to our own prosaic attempts at drawing a bowl of fruit to conclude that artistic creativity is something that is individualized and immutable. However, there is substantial research that shows evidence for strong situational factors influencing creativity. In some cases, intense negative emotions can create powerful self-reflective thought and perseverance, leading to increased creativity (De Dreu, Baas, & Nijstad, 2008; Kaufman & Baer, 2002; Verhaeghen, Joormann, & Khan, 2005; cf. Isen, 2000). In this article, we explore individual differences and situational factors related to creativity. We show that when individuals are biologically vulnerable to experiencing negative affect and are exposed to a situation that brings about intense negative emotion, they show the most artistic creativity.

Individual Differences in Creativity

Decades of empirical research on personality traits of highly creative individuals have identified a relatively consistent set of core characteristics of creative individuals. These traits include, for example, introversion, emotional sensitivity, openness to experience, and impulsivity (see Feist, 1998, for a review). At the extreme of affective personality factors linked to creativity are mood disorders. Historical figures in a variety of creative domains, ranging from Emily Dickinson to Robert Schumann, have been found to have suffered

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from depression and other mood disorders (Goodwin & Jamison, 1990; Ramey & Weisberg, 2004; Weisberg, 1994). Clinical, empirical, and biographical studies of creative individuals have shown that those in the creative arts suffer from significantly higher rates of mood disorders compared to matched controls (Andreasen, 1987; Ludwig, 1995), and mood disorders are 8 to 10 times more prevalent in writers and artists than in the general population (Jamison, 1993).

One way to index vulnerability to experiencing depression or negative mood is with biological products. Major depression is often associated with dysregulation of the hypothalamic-pituitary-adrenocorticol axis, which controls the release of adrenal steroids. One adrenal steroid that is commonly implicated in depression is dehydroepiandrosterone (DHEA) and its active metabolite DHEA sulfate (DHEAS). DHEAS levels have been found to be lower in those being treated for depression (Wolkowitz et al., 1997), and adrenal stimulation—resulting in increased DHEA levels—has been associated with lower symptom severity and improved mood in patient samples (Rasmusson et al., 2004). The anxiolytic effects of DHEA are believed to stem from its ability to counter-regulate the deleterious effects of high cortisol and as a precursor to sex hormones (see Epel, Burke, & Wolkowitz, 2007, and Southwick, Vythilingam, & Charney, 2005, for reviews). In this study, we examine DHEAS level and its link to artistic creativity.

Emotional Influences on Creativity

Although dispositional traits have been reliably linked to creativity, person-level factors are only half of the story; situational factors have been related to creativity as well. Literature on mood and creativity has demonstrated that both positive and negative affect can influence creative performance. Although some evidence suggests that positive mood can enhance creativity (see Isen, 2000, for a review), many other studies have demonstrated that negative affect can have a facilitative effect on creativity (see Kaufmann, 2003, for a review).

The contradictory findings regarding the effects of emotion on creativity stem from a variety of reasons, but the critical factors seem to be the type of task that is being used as the outcome of creativity and the nature of the emotional experience. Regarding the type of creativity, in some cases optimal creative performance may require elaboration and analytic processing with high detail orientation (Mackie & Worth, 1991; Schwarz, 1990). For example, it has been found that negative mood can result in enhanced solution frequency on creative tasks, particularly during tasks that require concentration, precise execution, divergent thinking, and analogical problem solving (Abele, 1992; Jausovec, 1989; Kaufmann & Vosburg, 1997). In other cases, optimal creative performance may require increased reliance on rapid, less effortful judgment heuristic strategies that show little systematic and analytic processing (Fiedler, 2000; Isen, Daubman, & Nowicki, 1987).

The type of emotional state appears to have an influence on creativity as well. In a recent meta-analysis, Baas, De Dreu, and Nijstad (in press) propose that in addition to positive and negative mood, level of activation should be examined in an effort to better understand the relationship between mood and creativity. Specifically, they offer evidence that activating mood states (i.e., anger, fear, happiness) versus deactivating mood states (i.e., calm, relaxed, sad, depressed) can differentially affect creative performance. In their dual pathway model of creativity (De Dreu et al., 2008), activating moods that are negative in hedonic tone are believed to enhance creative fluency and originality through enhanced perseverance. In contrast, activating moods that are positive in hedonic tone enhance creative fluency and originality through enhanced cognitive flexibility. In this research, we focus on a creative task that required concentration, high detail orientation, and originality (Amabile, 1996), and we manipulated high-arousal, activating emotional states.

Person × Situation Model of Artistic Creativity

Research suggests that creativity can be explained partly by personality characteristics but also by situational variables related to changing or enhancing affective states. A third option considers the interaction of person and situational variables, as evidenced through the classic interactionism approach (Endler & Magnusson, 1976). This approach suggests that situational factors can moderate the effect of person factors and has been used in a wide variety of social–psychological phenomena (see Mischel, 2004). In this study, we examined biological products linked to depression—DHEAS—and manipulated emotional states to test their combined effects on artistic creativity. We anticipated that engendering high-arousal negative emotions would bring about increased artistic creativity and that this effect would be exacerbated among those with lower levels of DHEAS—an index of affective vulnerability.

Study Overview

This experiment engendered high-arousal emotional states by exposing participants to a laboratory task (Trier Social Stress Task; Kirschbaum, Pirke, & Hellhammer, 1993) designed to elicit strong and enduring positive or negative emotional responses. We chose social feedback as our experimental manipulation

because decades of social–psychological research has shown that social approval, versus rejection, differentially affects mood, self-esteem, behavior, and physiology (Crocker, Cornwell, & Major, 1993; Dickerson, Gruenewald, & Kemeny, 2004; Leary et al., 2003; Mendes, Major, McCoy, & Blascovich, 2008).

During the initial task, participants received either explicit positive or negative feedback from a panel of interviewers during a mock job interview. Neuroendocrine responses (DHEAS) were assessed at the beginning of the experiment, and self-reported emotions were assessed throughout the experiment. Artistic creativity was assessed prior to and following the manipulation of emotional states.

There were three primary predictions that we tested. First, the *affective vulnerability prediction* tested the idea that participants who were biologically vulnerable—as indexed by lower DHEAS levels—would experience greater increases in negative affect after receiving rejecting social feedback. Second, we predicted that participants receiving social rejection would produce the most creative artistic products. Finally, we predicted a *person × situation interaction* such that biological products (DHEAS) would interact with situational triggers, eliciting high-arousal negative affect. Specifically, we expected that participants who were lower in DHEAS and who received rejecting social feedback would produce the most creative artistic products.

METHOD

Participants

We recruited 96 young adults (65 females) to take part in a 2-hour study on "physiological responses during various laboratory tasks." Participants were recruited via newspaper advertisements in the Boston area specifying adults between the ages of 18 and 25. We prescreened prospective participants for general health conditions and provided study day instructions that were intended to reduce factors that would influence neuroendocrine products (e.g., consuming dairy products with live cultures, use of caffeine, recent exercise, etc.; Kirschbaum & Hellhammer, 1994).

Procedure

Each participant arrived at the lab during afternoon hours and, after a 30-minute rest period, provided a saliva sample that we later assayed for DHEAS. Saliva was obtained in sterile tubes using the passive drool method, which requires participants to expectorate into a cryovial via a plastic straw. Upon completion of the study, saliva samples were stored immediately at –80 °C until they were shipped overnight on dry ice to a laboratory in College Park, Pennsylvania. Saliva samples were assayed for DHEAS using a highly sensitive enzyme immunoassay (Salimetrics).[1] The test used 50 ul of saliva per determination and has a lower limit of sensitivity of 10 pg/mL and a range of standard curve from 10.2 to 1,000 pg/mL; its average intra- and interassay coefficients of variation are 4.9% and 3.45%, respectively. Five samples could not be assayed because of either blood contamination or not enough saliva.

Baseline creativity. After the saliva sample was obtained, participants completed a creativity task, the Abbreviated Torrance Test for Adults (ATTA; Goff & Torrance, 2002), which was intended to serve as a baseline level of creativity. Participants were given 3 minutes to complete the task, which consisted of nine triangles on a page, and they were instructed to use the triangles "to make some pictures" that were "unusual" and "interesting" and to give each picture a title along a common theme.

Social evaluation task. Following the baseline creativity task, participants were instructed that they would be preparing and delivering an 8-minute speech followed by a 5-minute question-and-answer (Q&A) period in a mock job interview. Participants were randomly assigned to one of three evaluative conditions. In the two experimental conditions, the participants were instructed that they would be delivering the speech to two evaluators; in the control condition, the participants were instructed they would be delivering the speech alone in the room. Once the participants consented to this part of the study, for those in the experimental conditions two experimenters (one male, one female) entered the room to reiterate the task instructions. For those in the control condition, the experimenter repeated the instructions. Following the instructions, all participants were left alone for 2 minutes to prepare for the speech.

For those in the experimental conditions, after the preparation period the evaluators reentered the room and participants began the speech. At this point, the experimental conditions diverged into either the social approval or social rejection conditions. The role of the evaluators was carefully scripted, coordinated, and timed so that all participants had a consistent experience. Accordingly, the evaluators were trained to present themselves with confidence and assumed authority. The social approval condition consisted of the evaluators' giving explicit positive feedback (e.g., "You are very clear and manage to put your personality across. You are very self-assured and authentic, really great job") as well as exhibiting positive nonverbal behavior

during the participant's speech, for example, smiling, nodding, and leaning forward. In contrast, the social rejection condition consisted of evaluators' shaking their heads, frowning, and giving explicit negative feedback during the speech (e.g., "I felt that you could be much clearer and more articulate. Think about what you are saying before you say it").

Participants in the control condition were instructed by the experimenter to give a speech while alone in the room and then to answer questions that appeared on index cards. The control condition was designed to require similar metabolic demands associated with speaking but not engender any specific strong emotional state.

Self-report measures. We assessed demand and resources appraisals, emotional states, and participants' perceptions of how the interviewers evaluated them. Immediately following the speech, participants were queried regarding their resource appraisals of the situation (e.g., I had the abilities to perform well on the task; Mendes, Gray, Mendoza-Denton, Major, & Epel, 2007). Participants rated their agreement with each sentence on a 1 (*strongly disagree)* to 7 (*strongly agree*) scale. Self-reported emotions were assessed both prior to and after the speech task using the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988), which measures high-arousal, activated emotions. Participants rated their feelings on 20 emotional states (10 positive and 10 negative) using 5-point scales ranging from 1 (*not at all*) to 5 (*a great deal*). Positive and negative emotion scales were calculated for each time point and had high reliability (alphas ranged from .85 to .91). After both the speech and the Q&A tasks, participants assigned to the social evaluation conditions rated how well they believed each of the interviewers thought they performed (e.g., She thought I performed well on the task). Responses for the male and female judges were highly correlated ($\alpha = .91$), so we combined these responses into a single score.

Creativity task. After the speech task, participants were given 10 minutes to complete a second artistic creativity task.[2] Following procedures outlined by Amabile (1982), participants were given a 10-×-15-inch piece of cardboard, a bottle of glue, a bottle of glitter, and 54 pieces of felt and paper in various shapes, sizes, and colors and were told to make a collage on the cardboard. Participants were given the following specific instructions:

> Feel free to use any of the materials that you like, but you don't have to use any that you don't want to—it is entirely up to you. You are not required to use anything in particular; just make a collage that you find interesting.

This test of creativity has been demonstrated to yield reliable assessments of artistic creativity (Amabile, 1982). Following this task, participants were debriefed and thanked.

Creativity Assessment

We recruited local artists to judge the creative products generated by the participants following the consensual assessment technique guidelines (Amabile, 1982). Eight artists (four professional artists and four graduate students in studio arts) with an average of 10 years of studio art experience were scheduled one at a time to judge each collage, and a subset of these artists judged the baseline creativity task (the ATTA).[3]

Prior to evaluating each collage, the judges were asked to create their own collages and were given the same instructions as participants. They then proceeded to judge participants' collages. Each collage was rated on 21 dimensions, which were assessed by having the judges mark an *X* on an 18 mm line anchored from low to high with a midpoint labeled *medium*. Consistent with the consensual assessment technique, judges were asked to use their own subjective definition in rating each of the dimensions.

We performed exploratory factor analysis with varimax rotation on the 21 dimensions and found that 15 of the 21 dimensions loaded high on one factor (factor loadings > .38).[4] Interrater reliabilities were acceptable (alphas ranged from .65 to .88). Therefore, we created a single index of collage creativity per participant, averaged across judges and across the 15 dimensions, which forms our primary dependent variable of creativity ($\alpha = .96$).

RESULTS

Manipulation Checks

We first examined if the social feedback manipulations were perceived as intended. There was no ambiguity regarding the manipulated conditions of social rejection and approval. Participants in the social approval condition perceived the evaluators as liking their interviews more than those in the social rejection condition, $F(1, 44) = 26.33$, $p < .0001$ (Table 1). Social approval also resulted in participants' perceiving themselves as having more resources than those in the rejection condition, $F(1, 88) = 4.20$, $p < .05$. We created an index of emotional responses (negative emotion – positive emotion) to provide a single index of negative affect without the buffering effects of positive emotion. The negative affect index differed by condition, with those assigned to social rejection reporting less positive and more negative emotion (controlling for baseline emotional

TABLE 1: Means and Standard Deviations (in parentheses) of Perceptions of Judges, Emotions, Appraisals, and Creativity by Feedback Condition

	Feedback Condition		
	Social Evaluation		*Nonsocial*
	Rejection	*Approval*	*Control*
"[Judges] thought I performed well"[1]	3.1 (1.3)$_a$	5.1 (1.3)$_b$	–
Negative emotions[2, 3]	–1.1 (1.1)$_a$	–1.6 (1.1)$_b$	–1.4 (1.1)$_b$
Resource appraisals	3.7 (0.8)$_a$	4.3 (0.8)$_b$	3.9 (0.9)$_a$
Creativity	9.4 (1.8)$_a$	7.7 (1.6)$_b$	8.4 (2.0)$_b$

NOTE: Different subscript letters across rows indicate significant differences by condition.
1. We averaged ratings made for the male and female judges.
2. Emotion ratings were created by subtracting positive emotions from negative emotions, such that higher numbers indicate more negative emotions.
3. Means are adjusted for pretask emotion ratings.

TABLE 2: Zero-Order and First-Order Partial Correlations Among Primary Dependent Variables by Feedback Condition

	Feedback Condition: Control		
	1. DHEAS	*2. Negative Emotions*	*3. Creativity*
1. DHEAS	–	.23	.23
2. Negative emotions	.08	–	.23
3. Creativity	.21	.29	–

	Feedback Condition: Social Rejection		
	1. DHEAS	*2. Negative Emotions*	*3. Creativity*
1. DHEAS	–	.30	–.51**
2. Negative emotions	–.50**	–	.23
3. Creativity	–.53**	.44*	–

	Feedback Condition: Social Approval		
	1. DHEAS	*2. Negative Emotions*	*3. Creativity*
1. DHEAS	–	–.09	.14
2. Negative emotions	.00	–	.19
3. Creativity	.15	.24	–

NOTE: Zero-order correlations appear above the dashed diagonals; partial correlations appear below the dashed diagonals. Partial correlations control for pretask emotion ratings. Negative emotion ratings were obtained immediately following the question-and-answer task and were calculated by subtracting the average of positive emotions from negative emotions, such that higher numbers indicate more negative emotions. DHEAS = dehydroepiandrosterone-sulfate.
*$p < .05$. **$p < .01$.

responses) than those assigned to social approval, $F(1, 85) = 4.54$, $p < .04$. Given these findings, we were confident that we successfully manipulated social rejection and approval.

As an initial examination of our predictions, we explored zero-order and first-order partial correlations among our primary dependent variables by condition (Table 2). The partial correlations include pretask negative affect as a control variable to best assess changes in emotional responses as a result of the manipulated social setting. Significant relationships were found among DHEAS, creativity, and negative emotional responses, most notably from the social rejection condition. These relationships are explored below, organized by the specific predictions.

Affective Vulnerability

Our first prediction was that lower DHEAS would bring about greater increases in negative affect when participants received rejecting social feedback. However, we anticipated that this vulnerability would not be related to changes in negative affect following social approval or the nonsocial condition. To establish this initial effect, we conducted hierarchical regression analyses in which the first step included baseline DHEAS, condition effects (two effect-coded predictor variables to represent the three levels of evaluation; we coded social rejection as the reference condition), and pretask emotions as a covariate to predict the poststressor negative affect index. This first step produced an overall significant model ($R^2 = .487$, $p < .0001$). The second step included all the initial predictors plus the interaction terms (condition by DHEAS). As expected, the inclusion of the interaction terms significantly increased model fit ($\Delta R^2 = .041$, $p < .04$). Supporting the affective vulnerability prediction, following rejecting social feedback the lower the participants' DHEAS, the greater their negative emotional reactions ($b = -.07$, $p < .01$; Figure 1). The relationships between DHEAS and negative emotions were not significant following the social approval condition ($b = -.01$, *ns*) or following the nonsocial condition ($b = .02$, *ns*).

Effects of Social Rejection on Creativity

We then turned to predictions regarding creativity: Our second prediction was that social rejection would increase artistic creativity relative to the other two evaluative conditions, social approval and the control condition. To test this prediction, a regression analysis similar to the one described above was conducted, although this time we predicted creativity scores using baseline DHEAS and condition effects.[5] The main effect for DHEAS was not significant, but both condition

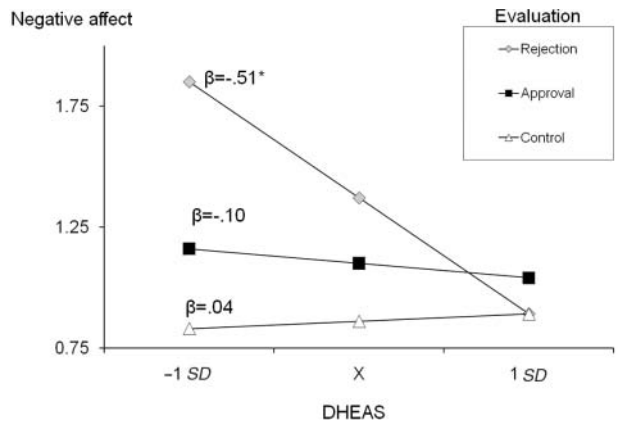

Figure 1 Relationships between dehydroepiandrosterone-sulfate (DHEAS) and negative affect by feedback condition, controlling for pretask emotions.
NOTE: Slopes are reported as standardized betas (β).
*$p < .05$.

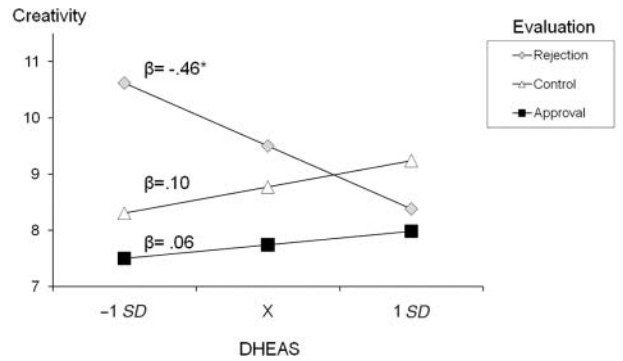

Figure 2 Relationships between dehydroepiandrosterone-sulfate (DHEAS) and creativity by feedback condition, controlling for pretask emotions.
NOTE: Slopes are reported as standardized betas (β).
*$p < .05$.

effects were: control versus rejection, $t(86) = -2.39$, $p < .02$, and approval versus rejection, $t(86) = -3.59$, $p < .0005$. As can be seen in Table 1, collages were judged to be the most creative following social rejection ($M = 9.4$), which significantly differed from the control condition ($M = 8.4$) and the social approval condition ($M = 7.7$).

Our final prediction was that the interaction between baseline DHEAS and the evaluation manipulation would predict artistic creativity. To test this interaction, we added a second step to the regression analysis described immediately above, after the main effects (condition and DHEAS) were accounted for in Step 1; Step 2 included the interaction terms. The change in R^2 with the addition of the interactions was significant, $\Delta R^2 = .074$, $p < .006$, as were the interactions: approval versus rejection, $t(80) = 2.28$, $p < .03$; and control versus rejection, $t(80) = 2.44$, $p < .02$ (Figure 2). Following social rejection, there was a significant negative relationship between DHEAS and creativity such that the lower baseline DHEAS, the higher the creativity scores ($b = -.14$, $p < .01$). DHEAS and creativity were not reliably related following social approval ($b = .02$, *ns*) or in the control condition ($b = .07$, *ns*).

How Social Rejection Affected Creativity: Mediational Analysis

Given our significant results for our targeted hypotheses, our final analyses included testing the possible mediating role of negative emotional responses. We would anticipate that negative emotional responses are one possible mechanism through which increased creativity occurred; however, we would only expect this to be the case following social rejection. Therefore, we expected that biological vulnerability (lower DHEAS) would make one more susceptible to experiencing greater negative emotions following rejecting social feedback and that these changes in emotions would then lead to greater artistic creativity. Therefore, we conducted a series of regression analyses in which we tested a mediated-moderation analysis; that is, the possibility that negative emotions would mediate the relationship between the Person × Situation interaction (DHEAS and evaluative condition) and creativity (Baron & Kenny, 1986). Because we predicted that the social rejection condition would be the only condition that yielded mediation, we used the same contrast codes as before so that the reference condition was social rejection. The first regression equation predicting creativity using the two Person × Situation interaction terms yielded significant effects for both terms: approval versus rejection, $t(82) = 2.69$, $p < .009$, and control versus rejection, $t(82) = 2.35$, $p < .02$ (Figure 3). The second regression equation used the Person × Situation interactions to predict negative emotional responses, controlling for prefeedback emotion ratings: approval versus rejection, $t(81) = 2.03$, $p < .05$, and control versus rejection, $t(81) = 1.79$, $p < .07$; the lower the baseline DHEAS, the greater the negative emotional response following social rejection feedback. The last regression equation predicted creativity scores using the Person × Situation interaction and negative emotional responses (mediator). Increased negative emotional responses predicted greater creativity scores, $t(80) = 2.54$, $p < .02$, and the direct relationship between the Person × Situation interactions and creativity were significantly reduced once negative emotional responses were included in the model: approval versus rejection, $t(80) = 2.11$ $p < .04$, Goodman test, 2.11, $p < .04$; and

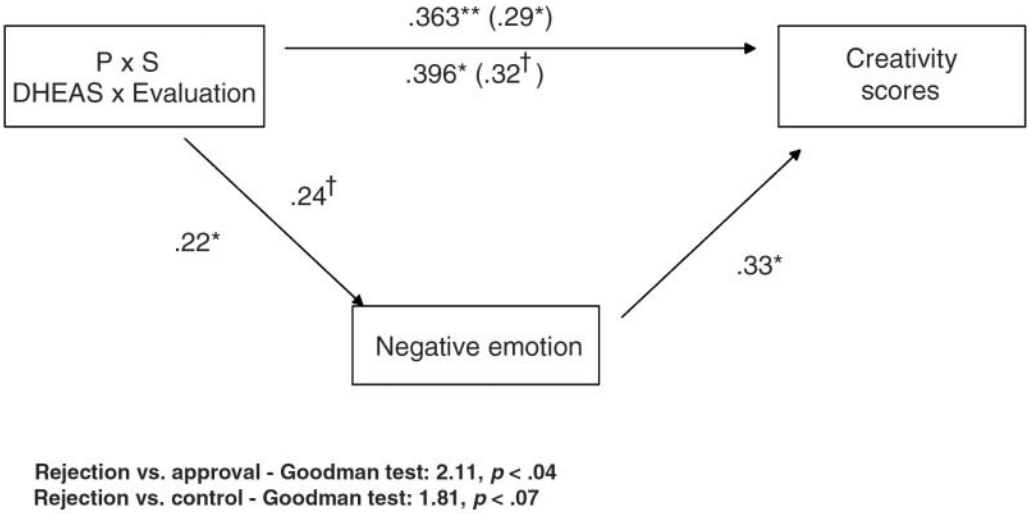

Figure 3 Mediated-moderation analysis testing the mediating role of negative emotional responses (high negative and low positive affect) as a causal factor of the Person × Situation (P × S) interaction and creativity scores.
NOTE: The outer path presents comparisons of social rejection to social approval; the inner path presents comparisons of social rejection to the control condition. Paths are reported as standardized betas (β). Asterisks indicate a statistically significant relationship. DHEAS = dehydroepiandrosterone-sulfate.
†$p < .10$. *$p < .05$. **$p < .01$.

control versus rejection, $t(80) = 1.92$, $p < .058$, Goodman test, 1.81, $p < .07$.

DISCUSSION

This experiment yielded four noteworthy findings. First, we found that lower levels of DHEAS resulted in greater affective vulnerability. When participants received rejecting social feedback, lower DHEAS was significantly correlated with greater negative emotional responses. DHEAS was not related to negative emotional responses following the social approval or nonfeedback conditions. This finding demonstrates support for the use of DHEAS as an indicator of affective vulnerability (see also Mendes, Ayduk, Akinola, & Epel, 2008). The second important finding was that social rejection resulted in greater artistic creativity than did the social approval or nonsocial situations. We believe that the use of a well-validated social task, which reliably yields strong emotional reactions, may have provided a test of how creativity is affected in the face of strong emotional manipulations eliciting activating moods, as opposed to the weaker or more subtle mood manipulations often employed (De Dreu et al., 2008; Isen, 2000). We also observed evidence for the person-by-situation model that we proposed. When individuals were more biologically vulnerable *and* exposed to a strong rejecting situation, they performed better on the artistic creativity task. Finally, we showed that negative emotional changes mediated the link between biological vulnerability and creativity for those receiving rejecting social feedback.

Research on how affect influences creativity suggests several pathways through which creativity may be enhanced. One possibility is that negative social evaluation increased creativity because participants ruminated more over negative feedback (Nolen-Hoeksema, 2000), thus potentially creating more distraction during the creative task. This distraction may have led to enhanced creativity because unconscious thoughts could influence the creative products without interference from conscious operations (Dijksterhuis & Meurs, 2006). The other explanation, in stark contrast to the unconscious thought facilitation explanation, is the possibility that creativity was enhanced because negative emotions produced powerful introspection and detailed thinking (Verhaeghen et al., 2005). Although these data were not meant to address how conscious and unconscious processes independently affect creativity, these data do show strong effects for negative emotional responses (both dispositionally and situationally) in enhancing creativity.

Another possibility is that negative social evaluation increased creativity because participants exerted more effort and worked harder on the creativity task after receiving negative feedback. Previous research has shown that negative feedback can lead to increased

subsequent effort (e.g., Anderson & Rodin, 1989; Campion & Lord, 1982; Podsakoff & Farh, 1989), as long as the task is not perceived as too difficult to be mastered (Locke & Latham, 1990). This is consistent with research indicating that when individuals experience negative affect in a situation that requires creativity, this negative affect may be interpreted as a signal that additional effort must be exerted for a creative solution to be discovered (George & Zhou, 2002; Martin, Ward, Achee, & Wyer, 1993). In contrast, positive mood coupled with a situation that requires creativity may be an indication that the creative goal has been met, reducing the amount of effort exerted on the task.[6]

Importantly, our findings are consistent with volumes of historical and empirical evidence relating depression to creativity. Although the data presented here provide support for the creativity and depression link, this general model would not, necessarily, be supportive of the proposed link between bipolar disorder and creativity because lower levels of DHEA have been linked to depression rather than to mania. In addition, mania is not typically characterized by strong negative emotional responses. Historical evidence suggests that many creative luminaries suffered from depression, but others suffered from bipolar disorder. One possibility regarding how creativity is influenced by affective changes due to bipolar disorder is that manic phases may increase the *quantity* and not the *quality* of the creative work (Weisberg, 1994). Mania might also be related to perceptions of how creative one believes oneself is, which might differ from how creative the person actually is. In support of this idea, Pronin and Wegner (2006) manipulated "mania" with thought-racing instructions and found that participants had more grandiose thoughts, including perceptions of enhanced creativity. Whether these participants actually were capable of enhanced creativity is not known. It is possible that mania provides the perception of creativity, which results in more attempts and hence increased productivity, but depressed states provide the introspection and careful deliberation that result in fewer but higher quality products.

Although extant research has offered some evidence for biological differences in creativity (Howard-Jones, Blakemore, & Samuel, 2005; Martindale, 1999), we believe our data demonstrate some of the first evidence linking biological products and social and emotional factors to predict complex behaviors such as creativity. There is mounting evidence that depression is linked to lower levels of DHEA and that DHEA supplementation can combat depression, but this is the first study that we know of that shows that lower baseline levels of DHEA make individuals more vulnerable to experiencing negative affect following social rejection. Furthermore, given this *affective vulnerability*, we showed that artistic creativity was enhanced following the increased negative mood state. Given the volumes of research on the links between depression and creativity, these data provide provocative evidence regarding possible underlying biological mechanisms involved in the depression–creativity link.

NOTES

1. We also assayed for cortisol because basal cortisol levels have also been linked to depression; however, we found no effects for cortisol with any of the results reported here.

2. Two participants did not create collages. One discontinued the experiment prior to being given instructions for the speech and question-and-answer task, and the other discontinued after the speech and question-and-answer task.

3. The Abbreviated Torrance Test for Adults was rated on five dimensions—creativity, originality, flexibility, elaboration, and fluency—utilizing a 5-point Likert-type scale ranging from 1 (*low*) to 5 (*high*). We examined interrater reliability on these five dimensions. The judges' agreement was acceptable across four of the five dimensions (alphas ranged from .65 to .76); elaboration was not reliably judged by the artists and thus dropped. We then examined reliability across the four dimensions, which yielded an acceptable alpha as well ($\alpha = .78$) and thus created a single index of baseline creativity.

4. The following six variables did not load high on the first factor: spontaneity, degree of representationalism, degree of symmetry, expression, movement, and variation of shapes; thus, they were not used in the creativity index. However, all analyses reported here were repeated with the creativity index calculated with all 21 dimensions ($\alpha = .94$), and the results were essentially the same.

5. We did not control for baseline creativity in any of the analyses examining artistic creativity, as baseline creativity was never a significant covariate and the results are essentially the same with or without this covariate.

6. In order to explore the possibility that negative social evaluation increased creativity because participants exerted more effort and worked harder on the creativity task after receiving negative feedback, we examined the amount of objective space used by participants in the collages as a proxy for effort. Our rationale was that the less objective space used in the collage, the greater the detail orientation, indicating that more effort had been exerted by participants in creating the collage. We hypothesized that participants who were lower in dehydroepiandrosterone-sulfate (DHEAS) and were assigned to social rejection would use less objective space in their collages. In order to measure the amount of objective space used in each collage, we took photographs of each collage and used Adobe Photoshop to first calculate the total number of pixels contained in each collage. We defined this value as the *total area* of the collage. For each collage, we then selected each object used in the collage (i.e., all of the felt and paper pieces used) to determine the number of pixels contained in the collage pieces, which we defined as the *space covered* in the collage. We then subtracted space covered from the total area to determine the number of pixels constituting *white space* in the collage, then calculated the amount of white space as a percentage of total space for each collage. We then used this percentage of white space value as our dependent variable of objective space, with higher percentages indicating that less space was used in the collage (i.e., there was more white space than covered space). We examined differences in objective space by experimental condition and found no significant effect for condition, $F(2, 88) = .06$, $p = .94$ (M approval = 61.0, M rejection = 62.2, M control = 60.8). We also found no significant interaction effect when we tested the interaction of DHEAS and feedback condition to predict white space: approval versus rejection, $t(81) = 0.30$, $p = .76$, and control versus rejection, $t(81) = 0.35$, $p = .72$. Although we found no support for our hypothesis, these results do not conclusively eliminate the possibility that effort played a role in our findings.

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