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Conscientiousness and stress exposure and reactivity: a prospective study of adolescent females

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Abstract Conscientiousness is associated with health, but the mechanisms remain poorly understood. To explore the role that stress might play, this study examined whether conscientiousness was associated with exposure and reactivity to life stress. This study followed 133 adolescent women every 6 months for 2.5 years. Participants completed a baseline measure of conscientiousness, and at each visit underwent a structured interview to catalogue episodic and chronic stress and had blood drawn to assess inflammatory processes. Participants higher in conscientiousness experienced fewer self-dependent episodic stressors and less academic and interpersonal chronic stress throughout the study. However, at times when they experienced higher levels of chronic interpersonal stress, they became more resistant to glucocorticoids. Higher levels of conscientiousness may protect adolescent women from exposure to certain stressors. However, when stress occurs, highly conscientious individuals may become more resistant to glucocorticoids, increasing their risk for processes that influence inflammatory conditions.

Keywords Conscientiousness · Health · Inflammation · Personality · Stress

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Introduction

Mounting evidence suggests that personality is an important determinant of life outcomes, with an influence similar in magnitude to cognitive ability and socioeconomic status (Roberts et al., 2007). For health, one personality trait that is particularly important in buffering against morbidity and mortality is conscientiousness. Conscientiousness refers to the extent to which individuals engage in planning, goal-setting, and careful task management to control impulses in a socially desirable manner (John et al., 2008). Numerous studies have documented a protective effect of conscientiousness across the lifespan, consistently showing that higher levels of the trait are associated with increased longevity (Kern & Friedman, 2008; Terracciano et al., 2008). Furthermore, conscientiousness has been linked to better medical outcomes in patient samples, including less physician-rated morbidity (Chapman et al., 2007), better immunologic control over HIV infection (O'Cleirigh et al., 2007), and reduced mortality in chronic renal disease (Christensen et al., 2002).

A previously studied pathway through which conscientiousness has been shown to confer a protective effect against poor health outcomes is by influencing health behaviors. In fact, different studies show that conscientiousness is related to a number of important behavioral correlates of mortality (e.g., more exercise, decreased alcohol and tobacco use) and indirectly affects health status through health behaviors (Bogg & Roberts, 2004; Hampson et al., 2007). However, this research also found a direct and independent link between childhood conscientiousness and adult health, suggesting that additional mechanisms may underlie the relation. One such mechanism through which conscientiousness may further shape health is through its influence on stress. Stress has been

defined as a process that entails a stimulus, an appraisal of the stimulus, and a response (Cohen et al., 1995). This view draws on a classic model holding that when stimuli, commonly referred to as stressors, are appraised as threatening and unmanageable, they elicit a psychological state that is experienced as stress, as well as a cascade of behavioral and biological adjustments (Lazarus & Folkman, 1984). Thus, in this paper we use "stress" as an umbrella term, meant to capture situations in which people were exposed to a stimulus they judged (or would be expected to judge) as an unmanageable threat.

From a stress perspective, conscientiousness may be associated with health by either exposing individuals to different levels of stress or by determining whether stress affects downstream processes related to disease (Bolger & Zucherman, 1995). This implies that as they tend to engage in careful planning, conscientious individuals may prevent stressful situations and their ramifications for health, because stress, particularly when chronic, is associated with the development and progression of a variety of illnesses (Cohen et al., 2007). A recent study found that individuals higher on one facet of conscientiousness, self-discipline, prospectively experienced fewer daily hassles than their low-conscientiousness counterparts (O'Connor et al., 2009). However, this research relied on self-reports of stress, which can show problems with reliability and validity and does not allow stress to be distinguished along conceptually important dimensions like chronicity or dependency (Monroe, 2008; Segerstrom & Miller, 2004).

In addition, conscientious individuals may also differ in their reactivity, or the psychophysiological changes that they experience as a result of a stress. Again, because they tend to employ careful planning, conscientious individuals may find especially effective ways to overcome stress that arises in their lives by persisting when other people might give up (Connor-Smith & Flachsbart, 2007; Watson & Hubbard, 1996). These actions could eliminate the stressor and attenuate the physiological consequences of stress and, in doing so, protect the individual against later health problems (for reviews, see McEwen, 2008; Miller et al., 2009). However, a conscientious individual's reactivity to stress may be context dependent. When a person is in full control over a situation (e.g., preparing for an academic exam), being highly conscientiousness might result in decreased reactivity to the stress due to the reasons discussed above. By contrast, when a person is not in full control of the resolution to a stressful situation (e.g., a fight with a romantic partner), behaviors associated with conscientiousness may interfere with flexible problem solving (Hogan & Ones, 1997), and highly conscientious individuals may experience increased reactivity. In support of this view, a need for control has been shown to be inversely associated with natural killer cell activity in individuals exposed to acute uncontrollable stress (Sieber et al., 1992). Similarly, conscientiousness has been linked to impaired delayed-type hypersensitivity skin responses after exposure to acute uncontrollable stress (Segerstrom et al., 2003).

One of the biological mechanisms thought to play a role linking stress to disease is systemic inflammation (Cohen et al., 2007). Normally, when the body becomes injured or infected, innate immune cells aggregate at the scene and release proteins that help clear pathogens and heal wounded tissues. These proteins are called pro-inflammatory cytokines, and interleukin-6 (IL-6) is among the most central of them. This response is critical for survival and generally adaptive. However, it must be regulated and terminated when the threat has dissipated. Otherwise, a persistent inflammatory responses can take hold and contribute to pathogenic processes that ultimately result in chronic illnesses, including heart disease, some cancers, and some neurodegenerative conditions (Ershler & Keller, 2000; Pai et al., 2004). As stress is associated with the dysregulation of inflammatory processes that ultimately result in systemic inflammation, the effects of conscientiousness on health may involve changing the nature of the inflammatory response to stress. Indeed, recent work with a large community based sample documented that individuals in the lowest tier of conscientiousness had a significantly increased risk of developing clinically high levels of IL-6 (Sutin et al., 2010). In another study, older adults higher in conscientiousness showed stably low levels of IL-6 over time (Chapman et al., 2011). However, as stress was not evaluated in either of these projects it remains unclear whether differential exposure or reactivity was a mechanism underlying this association. Indeed, reactivity to stress is known to vary greatly across people (McEwen & Stellar, 1993), thus there could be important individual differences in how conscientiousness shapes the sequelae of stress that are not captured in the main effects described in these studies.

To examine this gap in the literature the current project analyzed five waves of data from a sample of adolescent women over two and a half years. Studying how conscientiousness shapes health-related processes during childhood and adolescence is important, because the early decades of life are increasingly recognized as key developmental periods for shaping differential health trajectories across the lifespan (for reviews, see Dahl, 2004; Miller et al., 2011; Patton & Viner, 2007). Indeed, during adolescence, psychiatric conditions begin to increase in prevalence (Costello et al., 2003) and the pathogenic processes that underlie cardiovascular disease become apparent, as do risk factors like central obesity and high blood pressure (Berenson & Srnivasan, 2005). This highlights that processes that contribute to many of the chronic illnesses of adulthood and old age have roots in the early years of life (Shonkoff et al., 2009). Additionally, given the social and biological transitions it

entails, adolescence may be a time when the impact of life stress is relatively accentuated (Gunnar & Quevedo, 2007). Thus, understanding how individual differences in conscientiousness affect stress exposure and reactivity during adolescence may offer key insights into how early life psychosocial factors "get under the skin" to affect lifetime health. To our knowledge, this is the first study to prospectively examine the effect of conscientiousness on both stress exposure and biological reactivity in an adolescent sample. In addition, it addresses methodological problems of self-report checklists (Dohrenwend, 2006) by utilizing a semi-structured interview to assess stress exposure. This interview evaluates stress in a variety of life domains and allows us to make contextual judgments about its severity, whether it is acute or chronic in duration, and judge how much of a role the participant had in causing it to occur.

We hypothesized that adolescent women higher in conscientiousness at the beginning of the study would experience less acute and chronic stress over follow-up. We also predicted that when stress did occur, it would be less severe among individuals high in conscientiousness. Moreover, we predicted that only those episodic events that were dependent on the actions of the participant would be associated with conscientiousness.

To examine how conscientiousness might influence reactivity to stress, we also collected blood from participants every 6 months to evaluate key features of the inflammatory response. To provide a measure of systemic inflammation we quantified the amount of IL-6 present in each participant's serum. We also measured the magnitude of participants' inflammatory response to a microbial challenge by exposing their leukocytes to a bacterial product in vitro and measuring the amount of IL-6 produced. Finally, we assessed how well participants' immune cells were able to regulate the inflammatory process by treating their bacterially-stimulated leukocytes with the anti-inflammatory hormone cortisol. This served as a test of how sensitive the cells were to signals that normally inhibit the inflammatory response. We hypothesized that conscientiousness would serve in a protective manner, attenuating any pro-inflammatory response brought about by the occurrence of life stress when such stress was controllable. However, for life stress that was less controllable, we hypothesized that being higher in conscientiousness would be associated with increased reactivity.

Methods

Participants

Data for this project were collected as part of a larger longitudinal study on depression and atherosclerosis among adolescent women at high risk for developing depression. Participants were recruited from the Vancouver, British Columbia community through advertisements in schools, newspapers, and magazines. Young women were eligible for the study if they were (a) between 15 and 19 years old, (b) fluent in the English language, (c) free of acute and chronic medical conditions, (d) without current or a lifetime history of major psychiatric disorders, and (e) at high risk for developing a first episode of major depression. To qualify as high risk an individual had to either have a first-degree relative with a history of major depression, or had to score in the top quartile of the sample distribution of either the Dysfunctional Attitudes Scale (Weissman & Beck, 1978, March) or the Adolescent Cognitive Style Questionnaire (Hankin & Abramson, 2002).

A total of 157 participants were enrolled in the study between 2004 and 2007. One hundred and forty-seven of them were at high risk for developing depression; the remaining 10 were included as a low-risk comparison group. The current article focuses on 133[1] of these women who completed a baseline personality assessment and at least three of five possible follow-up visits during which episodic stress was measured. We chose this cut-off because major episodic stress was a relatively rare occurrence within any given 6-month window. Thus, to more accurately estimate stress occurrence, we wanted to observe participants for at least 18 months following baseline. The Research Ethics Board of the University of British Columbia approved this project. Written consent was obtained from all participants and for participants under the age of 18, a parent or guardian also provided consent.

Procedures

At baseline, the Structured Clinical Interview for the DSM-IV (First et al., 2002) was administered to screen for psychiatric disorders. Candidates without a history of major Axis I disorders were then enrolled in the project. During the rest of the visit they completed questionnaires and interviews, and had a blood sample drawn via antecubital venipuncture to assess inflammatory processes. Subsequent visits occurred every 6 months over two and a half years and followed a similar protocol. Participants were asked to fast prior to the visit and blood was always collected between 8:00 am and 11:00 am to control for diurnal variations in the biological variables.

[1] To increase power for these analyses, data from the original 10 person low-risk comparison group were combined with the high-risk group and analyzed together. There were no differences between low-risk and high-risk individuals on any of the variables relevant to the current project, and removing them from the analyses did not change the pattern of results.

Conscientiousness

Conscientiousness was assessed at the baseline visit using the conscientiousness subscale from the Big Five Inventory (John et al., 1991), a widely used and extensively validated self-report measure of personality (John et al., 2008). The conscientiousness subscale consists of nine statements (e.g., "I am someone who perseveres until the task is finished") and participants are asked to indicate the extent to which they agree with each statement on a scale ranging from 1 (*disagree strongly*) to 5 (*agree strongly*). Internal consistency of the scale was high in our sample (Cronbach's $\alpha = 0.80$).

Life stress

Exposure to stressful life experiences was measured using the Life Stress Interview (LSI; Hammen, 1991). The LSI is a semi-structured interview made up of open-ended questions used to probe the occurrence of episodic and chronic stress over the past 6 months. Episodic stress was defined as an event having a distinct beginning and ending (e.g., a fight with a boyfriend). When a probe revealed that episodic stress had occurred, the interviewer followed up with questions exploring the context and fallout surrounding the event. The interviewer later presented each event to our research team, without disclosing the participant's emotional response to the event. The team then rated by consensus the long-term contextual threat each event posed. Operationally, this meant considering the impact the stressful event would have on a "typical" person within the same situational and biographical context. Ratings were made on a scale from 1 (*no negative impact*) to 5 (*severe impact*). For example, a small argument with a friend was rated as 1.5 as such arguments are common and not expected to pose a lasting threat for the "typical" person. However, having one's parents divorce was rated as a 4 as parental separation typically poses a lasting threat to most adolescents. Additionally, the team assigned a dependence rating to each event, reflecting the extent to which the occurrence of the event depended on the actions of the participant. Dependence ratings ranged from 1 (*almost certainly independent*) to 5 (*almost certainly dependent*).

We used the LSI episodic data to create three variables for analysis. The first reflected the total number of stressful episodic events experienced over the follow-up period. Stressful events with impact ratings of 1.5 or higher were counted. (Events with ratings of 1, *no negative impact*, were not counted towards the total.) The other variables reflected the number of dependent and independent stressful events experienced over follow-up, using the midpoint of the rating scale as a breakpoint for differentiating them. Because some of the participants missed follow-up sessions, we corrected all of the stress variables for number of visits attended. Hence, these variables reflect the average number of stressful episodic events a participant experienced in a typical 6-month window of the study. Additionally, to determine whether conscientiousness might relate to the severity of stress we also created severity variables reflecting the highest impact episodic event a participant experienced during the study. This was done separately for dependent and independent events, as well as for all events, regardless of dependence status.

Besides probing for the occurrence of stressful episodic events, interviewers gathered information about ongoing difficulties in participants' lives. They focused on nine specific domains: Romantic relationships, close friendships, broader social life, family, school, work, finances, and personal and family health. In each domain the interviewer made a rating between 1 and 5, with higher numbers indicating more severe and persistent difficulties. (The LSI does not provide a dependence rating for chronic stress.) To evaluate the team's interrater reliability, audiotapes of interviews were periodically rated by all members. On 91% of occasions all members gave chronic stress ratings within half a point of each other (the average *ICC* of ratings across domains was 0.74). For the present article, we focused on two domains of life that would theoretically be most directly affected by conscientiousness. The first domain tapped interpersonal chronic stress. To assess this variable, a composite score was generated by averaging ratings across the romantic, friend, family, and social domains to form a single variable. This composite was validated in an earlier cross-sectional analysis of these data, in which it showed robust associations with inflammatory outcomes (Marin et al., 2007). The second domain pertained to academic stress. We did not examine financial stress as most of the participants were reliant on their parents. Finally, we did not examine stress related to the workplace or health as there was too little variance in these outcomes to merit analysis.

Inflammatory measures

Blood collected at each visit was used to model three features of the inflammatory response. First, the extent of systemic inflammation was assessed via levels of IL-6 in serum. IL-6 levels were measured in duplicate using commercially available high-sensitivity enzyme-linked immunosorbent assay (ELISA) kits (HS600B; R&D Systems, Minneapolis, MN), which have a minimum detection threshold of 0.039 pg/ml and inter- and intra-assay variability of less than 10%.

Second, we measured how aggressively the participants' white blood cells responded to an ex vivo lipopolysaccharide (LPS) challenge. This assay indicates how

aggressively cells make IL-6 following LPS exposure. For this assay, whole blood was drawn into lithium-heparin Vacutainers (Becton–Dickinson, Oakville, Ontario, Canada), diluted 10:1 with saline, and incubated with LPS (50 ng/ml; Sigma, St. Louis, MO) for 6 h at 37°C in 5% carbon dioxide. IL-6 was measured in duplicate with DuoSet ELISA Development kits (R&D Systems, Minneapolis, MN), which have a detection threshold of 0.7 pg/ml and inter- and intra-assay variability of less than 5%.

Finally, we measured sensitivity to signals that regulate inflammation. To do this, we quantified IL-6 production in cells that had been incubated with LPS and cortisol. Cortisol conveys anti-inflammatory messages to immune cells, and this assay measured their ability to respond to these signals by dampening IL-6 production. These procedures were modeled after previous work by Rohleder et al. (2002). They used cortisol rather than dexamethasone as cortisol is more physiologically relevant and has shown strong evidence of validity in recent work examining various aspects of stress and inflammation (Miller & Chen, 2010; Rohleder et al., 2009). Blood was diluted 10:1 with saline and dispensed into culture plates (Sigma Chemicals, St. Louis, MO) with LPS (50 ng/ml). Doses of hydrocortisone were added to four of the wells in varying concentrations (2.76×10^{-5} M, 2.76×10^{-6} M, 2.76×10^{-7} M, 2.76×10^{-8} M). The fifth well contained only LPS. The culture was incubated at 37°C in 5% carbon dioxide for 6 h. IL-6 levels were measured in duplicate using DuoSet ELISA Development Systems kits (R&D Systems). We then calculated the concentration of hydrocortisone needed to reduce IL-6 production by half. This is called the inhibitory coefficient-50 (IC50). IC50 s are inversely proportional to glucocorticoid sensitivity. Higher values indicate that monocytes are less sensitive to cortisol's anti-inflammatory signals. To correct for skewness, these data were log-transformed prior to analysis.

Confounders

Personality tendencies vary across demographic categories (Donnellan & Lucas, 2008; Goldberg et al., 1998; Hart et al., 2008), as does exposure to stress (Hatch & Dohrenwend, 2007). To evaluate the possibility that demographic characteristics might be contributing to any observed relationships, we statistically controlled for baseline age, ethnicity, and socioeconomic status. The majority of the participants (91%) identified as being of either Caucasian or Asian descent, so we dichotomously coded ethnicity as 0 for Caucasian and 1 for other. Socioeconomic status (SES) was measured as years of parental education, with the highest score of either parent included as a covariate. Additionally, because the sample was at high risk for having mood problems, which can trigger stress (Hammen, 1991), we statistically controlled for the severity of each woman's depressive symptoms at baseline (we note that the pattern of results did not change if depressive symptoms were omitted as a covariate). Symptoms were measured using the Beck Depression Inventory (BDI, Cronbach's $\alpha = 0.87$; Beck et al., 1961). Finally, when examining the reactivity hypotheses, we included other potential confounders known to affect inflammation. These variables reflected oral contraceptive use and average body mass index (BMI) during the study. Although smoking cigarettes has pro-inflammatory functions, only three of our participants endorsed regular smoking at any point during the study, which prevented us from modeling the effects of this variable.

Results

Demographics

Table 1 provides a reference of participant demographics and descriptive information for study measures. At study entry the participants were an average of 17.04 (SD = 1.39) years old. The sample was ethnically diverse with 64 (48%) of the participants identifying as being of

Table 1 Descriptive statistics ($N = 133$)

Variable	Mean	SD
Demographic Information		
Age in years (Visit 1)	17.04	1.39
Years of parental education (Visit 1)	15.92	3.37
Beck Depression Inventory scores (Visit 1)	7.01	5.99
Body mass index (Visits 1–6)	21.95	2.74
Conscientiousness (Visit 1)	3.51	0.66
Participants who used oral contraceptives at least once during study	$n = 65$	
Life Stress Interview (Visits 2–6)		
Number of dependent episodic events per 6 months	0.79	0.52
Number of independent episodic events per 6 months	0.76	0.51
Number of episodic events per 6 months	1.55	0.82
Highest severity episodic dependent event	2.31	0.65
Highest severity episodic independent event	2.56	0.87
Highest severity episodic event	2.72	0.83
Chronic interpersonal stress	2.42	0.47
Chronic academic stress	2.07	0.71
Inflammatory Measures (Visits 2–6)		
Serum IL-6, pg/ml	0.89	1.39
IL-6 production, pg/ml	48,164.57	17,304.53
Cortisol resistance, log(IC50)	$10^{-6.45}$	$10^{-0.31}$

Caucasian descent, 57 (43%) as being of East or South Asian descent, and 12 (9%) reporting some other ethnic identity. The participants were generally from families who were well educated. Their parents had spent an average of 15.92 (SD = 3.37) years in school. The majority of the sample ($n = 103$; 77%) completed the baseline and all five follow-up visits. Twenty-five (19%) of the participants completed four follow-up visits, and only seven (5%) participants completed three follow-up visits.

Attrition

We explored differences between participants who dropped out of the study prematurely and those included in the current analyses. Due to disproportionate group sizes, Welch's t test was used to explore differences. At baseline, the groups were similar on inflammatory measures ($ps > .50$), but differed on several psychological constructs. Those who dropped out were slightly less conscientious ($M = 3.15$, SD = 0.68) than those who stayed, $M = 3.51$, SD = 0.66, $t(28.01) = -2.31$, $p = .03$. They also had slightly higher levels of interpersonal chronic stress ($M = 2.59$, SD = .41) than those who stayed, $M = 2.35$, SD = 0.47, $t(34.36) = 2.50$, $p = .02$. Additionally, their most severe stressful episodic event at study entry ($M = 1.46$, SD = 0.76) was slightly less intense than for those who stayed, $M = 1.91$, SD = 0.83, $t(33.60) = -2.62$, $p = .01$. These results suggest that the final sample used for analysis was more conscientious and lower in stress than the population they were taken from which could lead to an underestimation of the actual effect.

Stress exposure

To test the stress-exposure hypotheses we first examined whether conscientiousness was related to the number or severity of stressful episodic events that participants experienced. To establish the temporal precedence of personality, we conducted these analyses in a completely prospective fashion. Conscientiousness scores at the baseline visit were correlated with episodic stress data collected during the subsequent two-year follow-up period. Because these relationships could be confounded by differences in age, ethnicity, SES, and depression, partial correlations were used to control for the contribution of these variables (Table 2 contains both the partial and the zero-order correlations). These data showed that conscientiousness was not related to the frequency of dependent, independent, or total stressful episodic events ($ps > .05$). It was, however, related to the severity of dependent events: Participants who were higher in conscientiousness experienced less severe events that they had played a role in causing, $r(126) = -0.22$, $p = .01$.

Hierarchal linear modeling (HLM) software (Raudenbush et al., 2004) was then used to examine whether baseline conscientiousness was related to trajectories of chronic stress. For these analyses the interpersonal and academic domains of chronic stress were evaluated in separate equations and inferences based on robust standard errors were considered due to non-normality. In the within-person (level 1) models, chronic stress was estimated as a function of months since the first follow-up. This provided an intercept that can be interpreted as the expected stress value at the first follow-up visit and a slope that can be interpreted as the trajectory of chronic stress over follow-up. In the between-person (level 2) models, we estimated these intercepts and slopes as a function of conscientiousness as well as the previously described covariates and a random error term. Results showed that to the extent that they scored higher in conscientiousness at baseline, participants tended to have less academic (upper panel of Fig. 1; $\beta = -0.19$, SE = 0.07, $p < .01$) and interpersonal (lower panel of Fig. 1; $\beta = -0.10$, SE = 0.05, $p = .04$) chronic stress 6 months later at the initial follow-up visit. These disparities in chronic stress persisted across the remainder of the follow-up period (i.e., conscientiousness was unrelated to slopes of chronic stress over time, $ps > .30$).

Table 2 Partial correlations between baseline conscientiousness and episodic stress measurements

	Average dependent events	Average independent events	Average events	Most severe dependent event	Most severe independent event	Most severe event
C[a]						
Pearson r	−0.05	0.06	0.00	−0.15	0.10	0.04
Partial r	−0.09	−0.03	−0.08	−0.22*	0.08	−0.03
p-value	0.30	0.75	0.38	0.01	0.38	0.75

Note: Zero-order Pearson correlations and partial correlations controlled for age and depressive symptoms at baseline, SES, and ethnicity. Significance tests are based on partial correlations

[a] *C* Conscientiousness

* $p < .05$

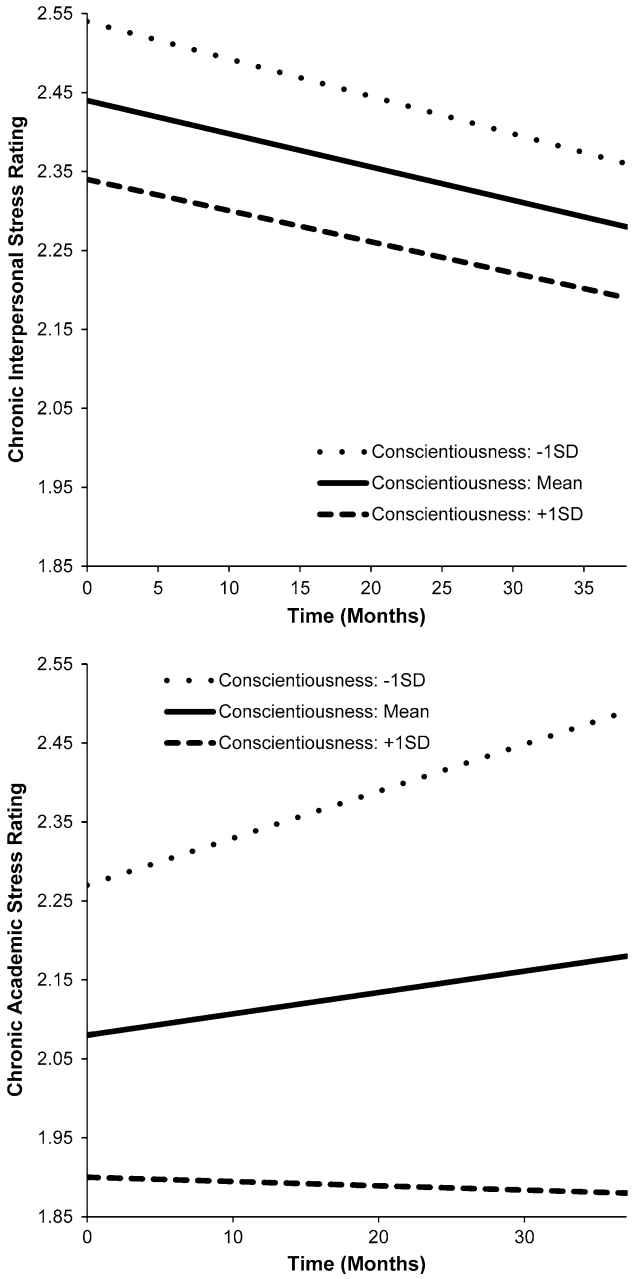

Fig. 1 Differences in chronic academic and interpersonal stress at first follow-up based on level of conscientiousness at baseline

Stress reactivity

Hierarchal linear modeling was also used to assess whether conscientiousness moderated associations between both episodic and chronic stress and the three inflammatory measures. Separate equations were developed to evaluate each of the different immune measures paired with each of the different life stress variables discussed above. Once again, only results based on robust standard errors were examined. In the within-person (level 1) models, the inflammatory process was estimated as a function of months since the first follow-up and the relevant person-centered stress index. This provided an intercept that can be interpreted as the expected value for the inflammatory measure at the first follow-up visit, assuming the participant was at her average stress level, and a time slope that can be interpreted as the trajectory of inflammation over 2 years, holding stress constant. Additionally, it provided a slope for the stress index that can be interpreted as the trajectory of inflammation as the participant deviated from her average stress level, holding time constant. In the between-person (level 2) models, we estimated these intercepts and slopes as a function of conscientiousness and a random error term. We also evaluated whether age, ethnicity, oral contraceptives use, and the participant's average BMI over the study might have confounded our analyses. The key coefficient for our stress reactivity hypothesis was the cross-level interaction between conscientiousness and life stress. A significant cross-level interaction for these variables indicates that conscientiousness moderated the impact of stress on the inflammatory outcome being considered.

Results indicated that conscientiousness did not act as a moderator of the associations between stressful episodic events and inflammatory outcomes (see Tables S1 and S2 in the online supplement; all $ps > .05$). Likewise, conscientiousness did not moderate the association of chronic stress with serum levels of IL-6 or IL-6 production following LPS challenge (see Tables S3 and S4 in the online supplement; all $ps > .05$). However, in models of glucocorticoid sensitivity, conscientiousness was significantly associated with the slope for chronic interpersonal stress ($\beta = 0.09$, SE $= 0.04$, $p = .02$). Simple slopes for this interaction were tested using previously described techniques (Preacher et al., 2006). As Fig. 2 shows, interpersonal stress was not related to glucocorticoid sensitivity among participants who were at or one standard deviation below the mean of the conscientiousness distribution (both $ps > .50$). But among participants who were one standard deviation above the mean of conscientiousness, increasing levels of interpersonal stress were associated with more resistance to glucocorticoid inhibition ($\beta = 0.12$, SE $=$ 0.06, $p = .04$). This pattern indicates that at visits when these participants had lower than their mean levels of stress, their cells were more sensitive to glucocorticoid inhibition than anyone else in the sample. This changed markedly at visits when they had higher than typical chronic interpersonal stress. At these times they were less glucocorticoid sensitive than others in the sample.

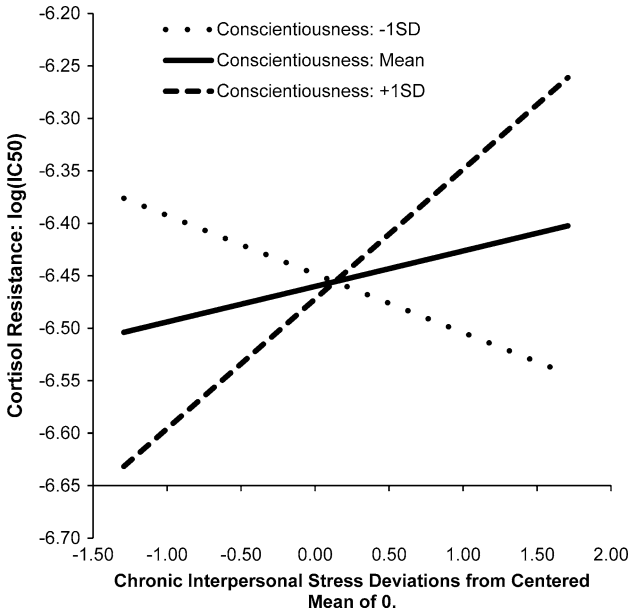

Fig. 2 Changes in cortisol resistance associated with deviations from mean levels of chronic interpersonal stress. Values on the *y* axis should be read as 10^{y}

Discussion

This paper provides partial support for the hypothesis that conscientiousness is related to stress exposure in adolescent women. Conscientiousness was unrelated to the number of dependent stressful episodic events that participants experienced. However, when events did occur, they tended to be less severe in more highly conscientious participants. Furthermore, conscientiousness was related to less chronic interpersonal and academic stress throughout the study. These findings are consistent with how conscientiousness has been previously conceptualized. Conscientiousness is characterized by being able to control impulses through careful thought and planning, and by setting goals and prioritizing actions (John et al., 2008). Thinking before acting may allow individuals to anticipate the results of their actions, and thus help them avoid situations that are likely to cause more stress. Of course, this argument suggests that conscientious individuals in our sample should have experienced fewer dependent stressful episodic events over the study, and they did not. What this pattern may suggest is that conscientious behavior does not prevent stressful events from occurring in the first place, but instead decreases the chances they will cascade into more severe and enduring difficulties. Alternatively, the null findings we observed for dependent stressful episodic events may reflect the relatively low frequency of such events in our sample.

We found modest evidence for the notion that conscientiousness influences the degree of inflammatory reactivity to stress. Conscientiousness did not emerge as a moderator in analyses relating life stress to levels of IL-6 in serum or white blood cell responses to LPS. However, there was evidence suggesting that it played a role in shaping how chronic interpersonal stress affected the glucocorticoid sensitivity of participants' leukocytes. To the extent that they were highly conscientious, participants became more resistant to glucocorticoid inhibition when their level of interpersonal chronic stress rose beyond normal. This finding is consistent with our hypothesis that highly conscientious individuals may not respond well if more severe stress is at least partially outside of their control. This pattern is also conceptually consistent with a recent longitudinal study which found that highly conscientious individuals who became unemployed during the course of follow-up experienced a much larger decrease in life satisfaction compared to their less conscientious counterparts (Boyce et al., 2010). The authors concluded that higher conscientiousness can be harmful when a person is faced with failure. Interpersonal stress can be viewed to some degree as a form of failure, in that it arises when something within a relationship breaks down.

We are reluctant to draw firm conclusions about how conscientiousness shapes stress reactivity given that the findings emerged for only one outcome and one type of stress. However, if these patterns are replicated in future research, they would have theoretical implications for our understanding of conscientiousness. Namely, when faced with stress, conscientious individuals tend to use active, problem-focused coping methods (Connor-Smith & Flachsbart, 2007; Watson & Hubbard, 1996). This form of coping is characterized by developing a goal to deal with the problem, allocating resources toward achieving that goal, and persisting until the goal is met and the problem has been solved. However, interpersonal relationships are defined by interacting with other people. Therefore, resolving a stressful interpersonal situation often requires action from another person. Thus, compared to other forms of more individually focused stress (e.g., academic problems), difficulties within one's social life may not always be solvable through active coping, making the strategies that the conscientious individual uses for dealing with the stress ineffective. When faced with the inability of overcoming such problems, maintaining persistence has been shown to be associated with high distress and elevated levels of systemic inflammation (Miller & Wrosch, 2007; Wrosch et al., 2007). Taken together, these findings suggest there may be certain types of stressful situations where being highly conscientious is not beneficial for health and wellbeing. This interpretation is consistent with Nettle's (2006) argument that being high on conscientiousness is not globally adaptive, but rather is associated with either costs or benefits dependent on the situation. It is also

consistent with Segerstrom's (2005) view of optimism's effects as being situationally dependent.

Why did conscientiousness moderate the relationship between chronic interpersonal stress and glucocorticoid sensitivity but not circulating IL-6 or IL-6 production? One potential explanation is that the effects of stress first become evident in disrupted crosstalk between regulatory systems. However, in young healthy people like the adolescents in the current sample, the immune system compensates for these changes through other regulatory processes, and in doing so prevents the kind of overshooting that would manifest in ongoing inflammation. However, repeatedly invoking these counter-regulatory responses through persistent exposure to more severe stress during the earlier years of life may change physiological set points, resulting in pathogenic changes that may be deleterious to future health (McEwen, 1998). Another possible explanation for these findings is that highly conscientious individuals in the current sample did not experience sufficiently high levels of stress. Indeed, individuals in the highest tier of conscientiousness only had an average interpersonal stress score of approximately 2.35 on a scale of 1–5 at their first follow-up visit, and this value actually declined slightly (although not significantly) over the course of follow-up. These possibilities need to be evaluated in studies with older samples who are experiencing more severe stressors.

Although our results imply a possible deleterious inflammatory consequence of high conscientiousness, recent work has documented that individuals higher in conscientiousness may actually be protected from inflammatory outcomes. For example, Sutin et al. (2010) found that individuals in the lowest part of the distribution for conscientiousness in a large population-based sample were at much higher risk for showing excessive levels of serum IL-6, and that each facet of conscientiousness was significantly negatively correlated with IL-6 levels. However, this study differed from the current project in that it assessed cross-sectional main effects of conscientiousness on inflammatory cytokines, whereas we examined conscientiousness as a moderator of the effects of within-person alterations of life stress. As we have argued, although conscientiousness may on average confer benefits to health, there may be certain situations where being high on the trait becomes a liability, and this would not be captured in a main-effects approach. Consistent with this line of reasoning, Chapman et al. (2011) showed that the beneficial effect of conscientiousness on IL-6 levels was largely attributable to increased goal striving. To the extent that the behaviors associated with the goal-striving facet are ineffective for resolving less controllable stressful situations, or even exacerbate those situations, the conscientious individual could in fact experience heightened biological reactivity. However, given the relative paucity of findings for our stress reactivity hypotheses, this formulation remains tentative and awaits replication.

This study's limitations need to be considered. First, the sample consisted of young women enrolled because they were at high risk for depression. It may be possible that this was a more resistant group of "high risk" individuals given that they had not experienced a depressive episode at time of study entry. Either way, due to their risk, our participants may have been more prone to experience life stress and may have reacted more severely when it did occur, limiting the generalizability of the findings. As such, future studies will need to substantiate them in more representative community samples. Second, our study was observational in nature. Although the hypotheses were tested in a prospective fashion, and some obvious confounders were controlled for, it is still not possible to make causal inferences about conscientiousness. Third, the low base rate of dependent stressful episodic events may have limited our power to detect associations with conscientiousness. Fourth, as the LSI captured stressful events that had occurred during the previous 6 months, there was often latency between when an episodic event actually occurred and when we drew blood to assess immune processes. As such, our immune measures were tapping not only reactivity, but also recovery, and possibly exposure to secondary stressors. Fifth, our findings suggest a scenario in which being overly conscientious may be deleterious to health, at least in some situations. If this is true, there may be a curvilinear association in the population, wherein conscientiousness is only beneficial up until a certain threshold. Our sample did not have enough individuals who were high enough in conscientiousness to be able to properly test for these effects, but doing so would be feasible as part of a re-analysis of some the larger-scale datasets already in the literature (e.g., Sutin et al., 2010). Sixth, we did not measure facets of conscientiousness and were thus unable to directly test whether planning specifically was responsible for the associations we observed. Although there is a clear theoretical foundation suggesting that planning is an important mechanism driving our findings, future research should explicitly examine this. Finally, evidence for the reactivity hypothesis was sparse, and in light of the number of analyses run the findings should be considered preliminary.

Despite these limitations, this study had several notable strengths. It had a multiwave prospective design that assessed life stress and inflammatory processes every 6 months over two and a half years. It also used interview methodology to assess life stress contextually, and distinguish it along important dimensions like chronicity, dependency, and severity. As a result of these strengths we were able to generate some preliminary insights into the

role that stress exposure and reactivity might play in shaping the health benefits of conscientiousness. Importantly, our study was able to glean these insights during adolescence, which is a period of social, psychological, and biological flux, where vulnerability to stress is accentuated, and life-course trajectories of health are being established. Our results suggest that the relationship between conscientiousness, stress, and health during the adolescent years is not clear cut. Conscientiousness does seem to reduce young women's exposure to severe stressful episodic events and more chronic social and academic difficulties, which may be beneficial insofar as adolescence is a time when severe life stress may be particularly impactful. However, when difficult interpersonal stress does arise, it may take more of a toll on those who are highly conscientiousness, at least for some physiological properties. Whether this extra toll offsets any health benefits of reduced stress exposure will be an important topic for later research. Also important will be to understand how these dynamics play out developmentally as adolescents make the transition into adulthood. In many cases, this transition will involve marked changes in the social and academic environment, as well as ongoing personality development and biological maturation. Long-term prospective studies will be necessary to unravel patterns of continuity and discontinuity in these processes.

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Conflict of interest All authors declare that there are no conflicts of interest and that they have full control of all data, which are available for review if requested.

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[Supplemental Digital Content 1]

Conscientiousness and Stress Exposure and Reactivity: A Prospective Study of Adolescent Females

Table S1

HLM Results for Episodic Stress Reactivity

Serum IL-6	Coefficient	Standard Error	*p*-value
Intercept	0.234	0.460	0.612
Age	0.144	0.270	0.596
Ethnicity	0.093	0.331	0.779
Oral Contraceptive Use	-0.109	0.533	0.838
BMI	-0.163	0.129	0.209
Conscientiousness	0.103	0.167	0.536
Cortisol Resistance: log(IC50)	Coefficient	Standard Error	*p*-value
Intercept	-0.107	0.070	0.130
Age	-0.068	0.030	0.026
Ethnicity	0.111	0.082	0.176
Oral Contraceptive Use	0.020	0.062	0.752
BMI	-0.019	0.035	0.592
Conscientiousness	0.060	0.039	0.125
IL-6 Production	Coefficient	Standard Error	*p*-value
Intercept	107.643	3537.072	0.976
Age	-1389.683	1382.467	0.317
Ethnicity	2197.044	3337.197	0.511

Oral Contraceptive Use	-829.002	3495.251	0.813
BMI	-808.437	1208.207	0.504
Conscientiousness	-950.416	1940.400	0.625

Note. For these analyses, episodic stress was coded as 0 = No Occurrence of 2.5+ Magnitude Event and 1 = Occurrence of 2.5+ Magnitude Event

Table S2

HLM Results for Episodic Stress Reactivity Measured as Most Severe Event at Each Visit

Serum IL-6	Coefficient	Standard Error	*p*-value
Intercept	0.246	0.255	0.336
Age	0.149	0.155	0.339
Ethnicity	-0.004	0.253	0.987
Oral Contraceptive Use	-0.348	0.290	0.232
BMI	-0.152	0.090	0.095
Conscientiousness	0.172	0.115	0.138
Cortisol Resistance: log(IC50)	Coefficient	Standard Error	*p*-value
Intercept	-0.064	0.061	0.298
Age	0.000	0.021	0.878
Ethnicity	0.004	0.055	0.947
Oral Contraceptive Use	0.062	0.059	0.289
BMI	-0.043	0.018	0.018
Conscientiousness	0.007	0.048	0.878
IL-6 Production	Coefficient	Standard Error	*p*-value
Intercept	679.407	1660.775	0.683
Age	-1194.027	785.934	0.589
Ethnicity	774.053	1973.134	0.695
Oral Contraceptive Use	-698.143	1785.929	0.696
BMI	-293.038	716.554	0.683
Conscientiousness	623.396	1152.669	0.589

Table S3

HLM Results for Chronic Academic Stress Reactivity

Serum IL-6	Coefficient	Standard Error	*p*-value
Intercept	0.219	0.224	0.331
Age	0.191	0.095	0.045
Ethnicity	-0.239	0.226	0.292
Oral Contraceptive Use	-0.061	0.201	0.761
BMI	-0.064	0.071	0.370
Conscientiousness	-0.027	0.076	0.721
Cortisol Resistance: log(IC50)	Coefficient	Standard Error	*p*-value
Intercept	-0.141	0.067	0.036
Age	0.000	0.029	0.995
Ethnicity	0.163	0.070	0.023
Oral Contraceptive Use	0.132	0.060	0.030
BMI	-0.021	0.021	0.322
Conscientiousness	0.017	0.023	0.463
IL-6 Production	Coefficient	Standard Error	*p*-value
Intercept	-7763.068	3494.525	0.028
Age	-2143.290	1653.917	0.102
Ethnicity	8926.913	3429.229	0.011
Oral Contraceptive Use	2647.929	3392.478	0.437
BMI	264.108	1237.015	0.831
Conscientiousness	1962.886	1192.078	0.102

Table S4

HLM Results for Chronic Interpersonal Stress Reactivity

Serum IL-6	Coefficient	Standard Error	*p*-value
Intercept	0.041	0.834	0.961
Age	0.067	0.521	0.898
Ethnicity	0.700	0.614	0.257
Oral Contraceptive Use	-0.501	0.894	0.576
BMI	-0.096	0.232	0.678
Conscientiousness	0.037	0.311	0.905
Cortisol Resistance: log(IC50)	**Coefficient**	**Standard Error**	***p*-value**
Intercept	0.034	0.074	0.646
Age	-0.006	0.040	0.884
Ethnicity	0.018	0.086	0.833
Oral Contraceptive Use	-0.034	0.073	0.641
BMI	0.027	0.032	0.403
Conscientiousness	0.090*	0.038	0.019
IL-6 Production	**Coefficient**	**Standard Error**	***p*-value**
Intercept	-1077.705	4251.962	0.800
Age	-2687.038	1915.845	0.655
Ethnicity	-1298.636	4291.607	0.763
Oral Contraceptive Use	-1316.221	3670.201	0.720
BMI	-4909.165	1854.279	0.010
Conscientiousness	-848.509	1896.829	0.655

*$p < .05$.