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Neuroticism and introversion are associated with salivary cortisol patterns in adolescents

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Summary Previous studies have yielded equivocal findings on the relationship between personality and cortisol activity. The present study examined associations between personality and cortisol activity in a large, diverse adolescent sample, while partialling the effects of relevant demographic and health-related covariates. A subsample of 230 participants (57% of whom reported elevated neuroticism) was selected from a larger sample of 16—18-year olds involved in a study on risk factors for emotional disorders. Subsample participants completed a battery of personality questionnaires, and saliva collection was requested several months later on three consecutive days at six time points per day, from wakeup to bedtime. Associations between personality and cortisol rhythms were examined using multilevel growth curve modeling. Neuroticism (N) and introversion (I) were significantly and differentially associated with features of diurnal cortisol patterns. Specifically, a significant N × gender interaction was observed, demonstrating flatter cortisol rhythms across the waking day among male participants with higher N. Elevated I, however, was associated with lower cortisol awakening responses for both male and female participants, and higher cortisol at the time of waking for male participants only. The present study supports personality as a significant predictor of diurnal cortisol patterns in late adolescence, after accounting for the effects of demographic and health covariates, and suggests that gender plays a role in moderating associations between personality and cortisol.

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In the search for risk factors of mood and anxiety disorders, there has been a burgeoning interest in the role of neuroticism (N), a relatively enduring personality trait associated with a proneness to experience negative emotions and thoughts (e.g., Costa and McCrae, 1980; Eysenck, 1967)—including anxiety, hostility, depression, self-consciousness, impulsiveness, and vulnerability (Costa and McCrae, 1995). N has been shown prospectively to predict the development of emotional disorders, including major depression, post-traumatic stress disorder (PTSD), phobias, and panic attacks (e.g., Breslau et al., 1995; Clark et al., 1994; Hayward et al., 2000; Krueger et al., 1996). The personality trait of introversion (I) has also been of interest as a risk factor for social phobia and major depression chronicity (e.g., Clark et al., 1994; Trull and Sher, 1994). Introversion (i.e., low extraversion) is represented by low levels of warmth, gregariousness, assertiveness, activity, excitement-seeking, and positive emotions (Costa and McCrae, 1995).

1. Personality and HPA-axis function

Investigations of the biological correlates of N and I may contribute to our understanding of potential pathways by which N and I relate to emotional disorders. One important biological system that has been examined in relation to N and I is the hypothalamic—pituitary—adrenal (HPA) axis—one of the major neurobiological systems mediating the stress response. There are significant theoretical reasons why N and I may be related to variation in HPA-axis regulation. An essential aspect of personality involves individual differences in cognitive appraisal, which have known influences on HPA-axis activity (e.g., Gaab et al., 2006). For instance, a central element of N is the tendency to interpret events as harmful, which is associated with increased negative affect (NA). Increases in negative affect in response to stress have also been associated with increases in cortisol, a primary product of the HPA (Adam, 2006; Schlotz et al., 2006). Furthermore, a central element of I is the tendency to withdraw socially, often due to the overestimation of social evaluation and threat. Such fear of negative social evaluation has been shown to elicit acute cortisol elevations (Dickerson and Kemeny, 2004).

Although associations between HPA-axis function and personality may seem intuitive, previous evidence for the presence of such associations has been mixed. Several researchers using adult samples have reported no significant associations between personality (including neuroticism and introversion) and various measures of cortisol, including: (a) average basal cortisol concentrations (Schommer et al., 1999); (b) responses to the Dexamethasone Suppression Task (DST), which measures HPA negative feedback sensitivity to a synthetic glucocorticoid (Roy, 1996); and (c) cortisol responses to standard laboratory stress tasks (Kirschbaum et al., 1992; Schommer et al., 1999). Among studies that *have* found significant associations, the directions of these associations have been mixed—for example, high N has been associated with both increased and decreased responses to the DST (McCleery and Goodwin, 2001; Zobel et al., 2004).

1.1. Personality and diurnal cortisol patterns

Important indicators of cortisol functioning can be found both when gathering levels of cortisol across the whole day and when examining the pattern of changes across the day. Some of the most informative studies on personality and cortisol have obtained multiple cortisol samples across the waking day in order to examine diurnal cortisol patterns (e.g., Polk et al., 2005). Cortisol levels are typically high upon awakening, increase in the 30—40 min post-awakening (known as the *cortisol awakening response*, or *CAR*), and are followed by a steady decline to near zero values at bedtime (Kirschbaum and Hellhammer, 1989; Pruessner et al., 1997). The CAR is increasingly considered to be an important indicator of individual differences in HPA-axis activity (Clow et al., 2004). Individual differences in the size of the CAR are thought to have a strong genetic component (Clow et al., 2004) but are also responsive to psychosocial experience. Specifically, increases in chronic psychosocial stress (Clow et al., 2004; Schmidt-Reinwald et al., 1999) and psychosocial experiences on the days of cortisol testing (Adam et al., 2006) have predicted a larger CAR. It has also been suggested, however, that the *absence* of a CAR under situations of stress may reflect HPA-axis dysregulation (Adam et al., 2006; Gunnar and Vazquez, 2001).

The slope of cortisol rhythm across the waking day is also an important indicator of HPA-axis function. It is thought to be highly subject to psychosocial influences, with flatter diurnal cortisol slopes having been associated with increased experience of negative affect on the days of cortisol testing (Adam et al., 2006) as well as with the impact of accumulated chronic stress—in particular, interpersonal stress and/or trauma (Adam and Gunnar, 2001; Gunnar and Vazquez, 2001). Evening cortisol levels, which are an important contributor to cortisol slopes, appear to have less of a genetic component than wakeup cortisol levels or the CAR (Clow et al., 2004).

Associations between cortisol diurnal patterns and personality have been observed as early as childhood. Dettling et al. (1999) found that, among preschool boys, flatter diurnal slopes were associated with general negative affect, sadness, and shyness. Another study reported similar findings, with increased social fear predicting flatter diurnal cortisol slopes among preschool boys and girls (Watamura et al., 2003). When interpreted together, these two empirical studies support the association between flat diurnal slopes and the childhood temperamental traits of negative affect, sadness, shyness, and social fear. Importantly, these childhood temperamental traits have been shown to predict adult personality characteristics, with the childhood traits of negative affect and sadness significantly associated with N in adulthood (Rothbart, 2007), and the childhood traits of shyness and social fear significantly associated with I in adulthood (Rothbart, 2007). However, it remains to be seen whether these associations between flatter diurnal slopes and childhood precursors to N/I develop into associations between flatter slopes and increased N/I in adulthood.

There are very few adult studies examining associations between personality and diurnal cortisol. To our knowledge, the only study that has considered diurnal cortisol in the examination of both N and I in adults has yielded complex results. Polk et al. (2005) found that high trait negative affect was associated with higher total salivary cortisol and greater morning rise in men but not in women. In addition, cortisol levels for men who were low in positive affect (PA) followed a relatively high, flat rhythm, whereas women high in PA