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Cortisol stress resonance in the laboratory is associated with inter-couple diurnal cortisol covariation in daily life

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ABSTRACT

In laboratory environments individuals may display empathic cortisol stress responses merely from observing another experience psychosocial stress. Moreover, within couples, women synchronize their own to their partners' stress-induced cortisol release. We investigated whether a woman's tendency to experience such cortisol stress resonance in a controlled laboratory task is associated with the degree to which her and her partner's diurnal cortisol levels covary in a naturalistic environment. Such habitual cortisol covariation may be a pathway via which close relationships influence health outcomes. Forty-four men completed the Trier Social Stress Test while their female partners observed the situation, either via "real-life" (one-way mirror) or "virtual" (video) observation modality. Later, the couples collected diurnal cortisol samples over two weekdays. Hierarchical linear modeling indicated that the degree to which couples covaried in their daily cortisol secretion was associated with the female partner's cortisol stress resonance in the laboratory, and that this association was stronger if stress resonance was assessed in the "real-life" observation condition. Specifically, women with higher cortisol stress resonance were more closely linked to their partner's diurnal cortisol secretion. Neither momentary partner presence during sampling nor relationship duration or quality accounted for the association. By showing that covariation in the laboratory has ecological validity in naturalistic conditions, these results make an important methodological contribution to the study of dyadic processes. Given that close relationships exert immense influence over individual health outcomes, understanding the association between acute and chronic physiological linkage may provide important insight into the mechanisms by which close relationships impact well-being.

1. Introduction

Although we perceive ourselves as autonomous entities, our affective states are inevitably linked to those of our fellow human beings. One major component of affect sharing, empathy, describes the process of understanding the affective state of another by generating an isomorphic state in the self. Importantly, the empathic individual is fully aware that the source of the affective state lies in the other (de Vignemont and Singer, 2006). Social psychologists and neuroscientists have investigated motivational, ecological and behavioral foundations of empathy (Hatfield et al., 2009; Preston and de Waal, 2002; Singer, 2012) as well as mechanisms and neural networks underlying our capacity to empathize with others (e.g. Decety, 2011; Keysers et al., 2010; Lamm et al., 2011; Singer, 2006; Singer et al., 2004). At a physiological level, affective resonance is shown to translate to the autonomic nervous system (Ebisch et al., 2012; Harrison et al., 2006; Hein et al., 2011; Levenson and Ruef, 1992; Waters et al., 2014). In recent studies, our group and others demonstrated that empathic responses also permeate to the core of the stress system, the hypothalamic-pituitary-adrenal (HPA) axis (Buchanan et al., 2012; Engert et al., 2014). In detail, we induced empathic stress, i.e. physiologically relevant cortisol increases of 1.5 nmol/l above baseline levels (Miller et al., 2013), by asking participants to passively observe a target undergo a psychosocial laboratory stressor, the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). The emotional closeness between target and observer modulated the occurrence of empathic cortisol stress responses – specifically only 10% of strangers but 40% of romantic partners showed physiologically relevant cortisol release. Within the romantic partner dyads we detected a positive correlation between observers' and targets' stress responses. This phenomenon of proportionality between empathic and firsthand stress responses was termed cortisol stress resonance (Engert et al., 2014).

Resonating with the partner's stress response may have an adaptive value in that it improves mutual understanding or mobilizes energy to help. However, one could envision scenarios where stress resonance is maladaptive. Specific groups like the family members of chronically

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stressed individuals may be at risk for long-term cortisol stress resonance (Engert et al., 2014), which, through the stimulation of cortisol hypersecretion, may lead to detrimental health effects, including the promotion of cardiovascular, metabolic and autoimmune diseases (Chrousos, 2009; McEwen, 2008). For this mechanism to be plausible, individuals and their loved ones would need to be in synchrony not just in the laboratory but on a day-to-day basis. Indeed, others have argued that close relationships function within a rich context of daily challenges, major and minor life events, socioeconomic status and cultural influence. Thus, naturalistic methods may provide a truer reflection of couple processes than laboratory experiments (Laurenceau and Bolger, 2005; Scollon et al., 2003). Toward that end, the current study tested the ecological validity of laboratory-induced cortisol stress resonance by investigating whether an individual's tendency to synchronize to their partner's acute cortisol stress response relates to their degree of everyday diurnal cortisol linkage. While interwoven patterns of physiology are labeled with diverse terminology (e.g. resonance, synchrony, transmission, attunement), we refer to diurnal cortisol linkage as covariation, which best reflects the concurrent nature of couples' cortisol release (Butler, 2011).

Diurnal cortisol, a marker of HPA axis functioning, is the daily rhythm of cortisol levels peaking shortly after awakening and declining over the remainder of the day. Although much of the variation in diurnal cortisol can be attributed to day-to-day fluctuation, abnormal or flat diurnal cortisol profiles are associated with negative health outcomes (Ross et al., 2014). Previous research consistently demonstrates individual diurnal cortisol patterns to be linked within couple dyads (Liu et al., 2013; Papp et al., 2013; Saxbe et al., 2015; Saxbe and Repetti, 2010), yet relatively little is known about the factors which modulate this covariation. One study interpreted higher cortisol linkage during early mornings and evenings (compared to working hours) as partner presence effects (Saxbe and Repetti, 2010). However, succeeding work showed that explicit momentary ratings of togetherness did not account for or modify inter-couple covariation (Papp et al., 2013). Also, while cortisol covariation was related to poorer relationship quality (Liu et al., 2013; Saxbe et al., 2015; Saxbe and Repetti, 2010), it was positively associated with relationship connectedness as quantified by the amount of time couples report spending together (Papp et al., 2013). Understanding specifically if and how acute laboratory-induced stress resonance between couples relates to their degree of diurnal cortisol covariation may elucidate one possible pathway via which close relationships influence health outcomes (Holt-Lunstad et al., 2010; Uchino, 2009).

We studied a sub-sample of 44 opposite-sex couples involved in our aforementioned empathic stress study (Engert et al., 2014). In addition to completing the TSST in the laboratory, each couple collected diurnal cortisol samples over the course of two non-consecutive weekdays. Partner presence at time of saliva self-sampling was assessed. We hypothesized that women who are more susceptible to exhibit cortisol stress resonance within the acute laboratory setting, are also more closely linked to their partners' diurnal cortisol rhythm. Following up on previous inter-couple physiological linkage research (for review see Timmons et al., 2015), we further explored whether the association between cortisol stress resonance and diurnal cortisol covariation was explained by the couple's momentary physical presence during sampling, relationship duration or self-reported relationship quality.

2. Materials and methods

2.1. Participants

Participants were part of a larger collaborative study between Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig and Technische Universität Dresden. Out of 111 opposite-sex couple dyads involved in the original empathic stress study (Engert et al., 2014), only the 51 Leipzig couples were asked to take part in the follow-up research. With 7 couples choosing not to participate, the final sample comprised of 44 couples (age mean ± SD: 25.72 ± 3.92 years, range: 19–35 years). Of those 44 couples, 24 female observers watched their partner's stress more directly through a one-way mirror ("real-life" condition), and 20 female observers watched via live video transmission ("virtual" condition).

Given a potential effect on cortisol activity, regular recreational drug users (consumption within the past six months), smokers and individuals reporting chronic illness (including psychological disorders) or taking medication known to influence the HPA axis were excluded before the final sample selection. Female participants did not use hormone-based birth control and all (laboratory and home-based) data collection took place during the luteal phase of their menstrual cycle to control for the confounding effects of hormonal status on cortisol levels (Kajantie and Phillips, 2006). On average, 28.18 ± 60.22 days (range 1–207 days) elapsed between the laboratory visit and the diurnal sampling. At the time of testing, all couples had been in a continuous relationship for at least 6 months (duration mean ± SD: 38.17 ± 31.83 months, range: 6–168 months) and 70% were cohabiting. The study was approved by the Research Ethics Board of Leipzig University (ethics number: 360-10-13122010). Participants gave their written informed consent, could withdraw from the study at any time and were financially compensated.

2.2. First-hand and empathic stress inductions from the original study

Since cortisol secretion is characterized by a strong circadian rhythm (Dallman et al., 2000) stress testing in our original study was performed between 12:00 and 18:00 in a single 130-min session. Couples were separated upon arrival to the laboratory and allowed to rest for 30 min before receiving further instructions (Fig. 1). In order to account for possible sex differences in biobehavioral stress responses (Kajantie and Phillips, 2006), men were assigned the role of the target in the TSST while women were assigned the role of observer. In short, after a preparatory anticipation phase of 5 min, male targets were required to give an audio- and video-recorded mock job talk (5 min) and engage in difficult mental arithmetic (5 min) while being probed and evaluated by a committee of two alleged behavioral analysts. Women passively observed their partner undergo the TSST in two different conditions either through a one-way mirror or via live video transmission. To control for confounding sources of firsthand stress, women received a signed document guaranteeing that they would not be subjected to the stress test themselves. Nine salivary cortisol samples were collected between 20 min prior to and 60 min after the TSST in both partners. Because studies have shown that social support from the partner has opposite effects on cortisol release in men and women undergoing the TSST (Kirschbaum et al., 1995), men were not explicitly told that their partners would be watching their performance.

2.3. Salivary cortisol sampling

Cortisol was sampled using Salivette collection devices (Sarstedt, Nümbrecht, Germany) and stored at − 20 °C. For stress testing in the laboratory, saliva samples were taken from both targets and observers at − 20 and − 10 min, immediately after stressor cessation (10 min) and at 20, 30, 40, 50, 60 and 70 min relative to stressor onset (at 0 min) to fully capture hormone peak and recovery (Fig. 1). At the end of the laboratory visit, couples received cortisol sampling kits and detailed verbal and written instructions on how to self-collect saliva samples. Couples chose two non-consecutive weekdays within one week for their sampling routine. The sampling days were scheduled in the luteal cycle phase of the female partners. All participants received a phone or email reminder on the day prior to the sampling routine. Six samples were collected per sampling day: immediately upon free awakening (before getting up from bed), 30 and 60 min thereafter and at 3 pm, 6 pm and 9 pm for a total of 24 samples per couple (Fig. 2). Participants were