Cortisol increase in empathic stress is modulated by emotional closeness and observation modality

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Vicarious stress; Stress resonance; Empathy; Hypothalamic-pituitary-adrenal axis; Cortisol

Summary Stress disorders are among the most commonly occurring of all mental disorders. In this context, the question arises whether the stress inevitably unfolding around us has the potential to “contaminate” and compromise us. In the current multi-center study, we investigate the existence of such empathic stress (defined as a full-blown physiological stress response that arises solely by observing a target undergoing a stressful situation), and whether empathic stress permeates to the core of the stress system, the hypothalamic-pituitary-adrenal (HPA) axis. Additionally, we investigate whether empathic stress responses may be modulated by the familiarity between observer and target (partners vs. strangers), the modality of observation (real-life vs. virtual) and observer sex (female vs. male). Participants were tested in dyads, paired with a loved one or a stranger of the opposite sex. While the target of the dyad (n = 151) was exposed to a psychosocial stressor, the observer (n = 211) watched through a one-way mirror or via live video transmission. Overall, 26% of the observers displayed physiologically significant cortisol increases. This empathic stress was more pronounced in intimate observer-target dyads (40%) and during the real-life representation of the stressor (30%). Empathic stress was further modulated by interindividual differences in empathy measures. Despite the higher prevalence of empathic stress in the partner and real-life observation conditions, significant cortisol responses also emerged in strangers (10%) and the virtual observation modality (24%). The occurrence of empathic stress down to the level of HPA-axis activation, in some cases even in total strangers and when only virtually witnessing another’s distress, may have important implications for the development of stress-related diseases.

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1. Introduction

Stress is a major health threat in today’s fast-paced society. Stress disorders are among the most commonly occurring of all mental disorders (WHO International Consortium in Psychiatric Epidemiology, 2000). Whether or not we directly suffer from stress, the question arises how much the stress inevitably unfolding around us has the potential to negatively affect us. While phenomena like “stress contagion” or “empathic stress” receive major media coverage, solid empirical evidence for such empathic stress permeating to the endocrine level is lacking. The aim of this project was to examine whether empathic stress indeed exists on different levels of the physiological stress system.

No matter how strongly we perceive ourselves as autonomous entities emphasizing our individuality, our affective states are linked with those of our fellow human beings. The theory of Einfühlung (“feeling into”) by the philosopher Lipps (1897) marked the first scientific approach to explain how humans understand the affective states of others. Following this early philosophical perspective, social psychologists (Stotland, 1969; Batson, 1991; Eisenberg, 2000; Hoffman, 2000; Batson, 2009; Hatfield et al., 2009) and neuroscientists have stressed the notion of empathy (Preston and de Waal, 2002; de Vignemont and Singer, 2006; Decety, 2011; Singer, 2012), showing that affective resonance permeates to the autonomic nervous system (Levenson and Ruef, 1992; Harrison et al., 2006; Hein et al., 2011) and the brain (Singer and Lamm, 2009; Keysers et al., 2010; Lamm et al., 2011). In the context of the social neurosciences, empathy was defined as the process by which an individual infers the affective state of another by generating an isomorphic state in the self, all the while realizing that the source of the affective state lies in the other, not the self (de Vignemont and Singer, 2006; Singer and Lamm, 2009).

Considering the growing interest in empathy research, it is curious that affective sharing on the level of the physiological stress system has virtually been ignored. Few studies addressed the topic: Sethre-Hofstad et al. (2002) examined mother–child dyads while mothers observed their children in a challenging situation, and found attunement of adrenocortical activity between high maternally sensitive mothers and their children. However, neither the mothers nor the children exhibited physiologically significant adrenocortical responses to the challenging situation. Examining facial thermal imprints of mother–child dyads while mothers observed their own and unknown children in a distressing situation, Ebisch et al. (2012) and Manini et al. (2013) found symmetrical attunement but neglected the endocrine stress component. Buchanan et al. (2012) examined participants who had the dual role of inducing stress in others while observing the resulting stress responses. Considering that the task of stress induction may be quite stressful in itself, the authors might have confounded firsthand and empathic stress responses.

To fill this gap, we conducted multiple studies across different laboratories searching for evidence of true empathic stress responses down to the hormonal level. Beyond sympathetic nervous system (SNS) activation as unspecific sign of general arousal, stress experience requires the activation of the hypothalamic-pituitary-adrenal (HPA) axis resulting in cortisol release (Chrousos, 2009; Hellhammer et al., 2009). We accordingly defined empathic stress as an endocrine stress response that arises solely by observing a target undergo a stressful situation, while any simultaneous SNS activation is referred to as empathic arousal. We further differentiated between two components of empathic stress: Vicarious stress is suggested to arise through the projection of an observer’s own stress response onto the target, irrespective of the target’s response. Stress resonance requires the degree of the observer’s stress response to be a function of the degree of the target’s stress response. Thus, while the magnitude of a vicarious stress response is independent of the target’s stress response, observer’s and target’s stress responses are correlated in the occurrence of stress resonance. The same differentiation was applied to empathic arousal.

Empathic stress was examined in the following setting: While one participant underwent the Trier Social Stress Test (TSST; Kirschbaum et al., 1993; Kudielka et al., 2007), a psychosocial laboratory stressor, another solely observed the situation. HPA-axis activation was captured by repeated measurements of salivary cortisol in observers and targets. As empathetic indicators, we assessed the salivary enzyme alpha-amylase (Nater and Rohleder, 2009) and heart rate. As potential modulatory factors of empathic stress we systematically manipulated the familiarity between observer and target (partners vs. strangers), the modality of observation (real-life vs. virtual) and observer sex (female vs. male). Heterosexual partners constituted the intimate and opposite-sex strangers the distant relationship group. In the real-life observation modality, observers watched the TSST through a one-way mirror. In the virtual observation modality, they watched a close-up live video of the target’s face. Observers always watched an opposite-sex target (see Fig. 1A and B for an overview).

Our first goal was to find evidence for empathic stress down to the endocrine response level. Further, with regard to the two subcomponents of empathic stress, we expected a positive association between observers’ and targets’ cortisol responses as evidence for stress resonance. A significant portion of empathic stress was additionally expected to be independent of the targets’ cortisol levels, thus providing evidence for vicarious stress. Regarding potential modulatory factors, empathic stress was expected to be higher in intimate (partners) than distant (strangers) observer-target dyads and when observing from the real-life (one-way mirror condition) as compared to the virtual (video transmission) perspective. Given controversial evidence regarding sex differences in empathy (Eisenberg and Lennox, 1983; Baron-Cohen and Wheelwright, 2004; Singer et al., 2006; Rueckert and Naybar, 2008), no a priori hypothesis was formulated. Finally, previous work has shown correlations of subjective empathy measures (questionnaires or affect ratings) with empathy-related brain responses (Lamm et al., 2011). Based on these findings, we expected the magnitude of vicarious stress and stress resonance to be modulated by interindividual differences in trait and state empathy with higher empathy scores facilitating the occurrence of empathic stress.
2. Methods

2.1. Participants

This project was a collaboration between two research institutes. At the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, 51 opposite-sex couples and 40 male-female stranger dyads participated in the study. At the Technische Universität Dresden, 60 opposite-sex couples and 60 strangers were tested. To simplify the already complex study design, we limited the investigation to opposite-sex dyads. Couples had been in a relationship for at least six months. All participants were between 18 and 35 years of age. Stranger and couple dyads were not a priori age-matched. On average, however, they did not differ in age ($F_{1, 360} = 1.23; p > .20$). The Leipzig and Dresden samples differed in age (mean age in years ± SD in Leipzig: $25.64 ± 3.79$ and Dresden: $24.15 ± 3.93$; $F_{1, 360} = 13.13, p < .001$) but not in body mass index ($F_{1, 360} = 0.01, p > .90$) or educational status ($\chi^2(2, N = 356) = 2.66, p > .20$).

Figure 1  Overview of the experimental design and procedure. (A) While targets were exposed to the Trier Social Stress Test (TSST), observers solely watched the situation. For the observers, three potential modulatory factors were systematically manipulated: Relationship status (partners vs. strangers), observation modality (real-life through a one-way mirror or virtual via video transmission) and sex (female vs. male). (B) Participants attended one session at the laboratory (total session duration: 130 min). All participants underwent an initial resting period of 30 min. At 45 min after arrival, the targets were provided with the test instructions. Stress induction started at 50 min after arrival. Subsequent to the stress phase, participants were asked to rest for 60 min. Saliva samples (for cortisol and alpha-amylase assessments) were taken at 20 and 10 min before stressor onset, immediately after stressor cessation and in 10-min intervals thereafter (until 70 min after stressor onset). Heart rate was measured for a 5-min baseline between 15 and 10 min prior to stressor onset and during the 10-min stress phase. The target’s raw cortisol values are projected onto the experimental timeline showing a significant firsthand stress response to the TSST. The dashed red line marks what has been defined as a significant physiological cortisol stress response of at least 1.5 nmol/l over the baseline (Miller et al., 2013).
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 targeting the HPA-axis were excluded. Female participants did not use hormone-based birth control. The study was approved by the Research Ethics Boards of Leipzig and Dresden Universities (ethics numbers: 360-10-13122010; EK 352112010) and performed in agreement with the Declaration of Helsinki. All participants gave their written informed consent and could withdraw from the study at any time.

2.2. Experimental design and procedure

Since cortisol secretion is characterized by a strong circadian rhythm (Dallman et al., 2000; Fries et al., 2009), testing was performed between 12 and 6 pm in one 130-min session. Participants underwent a physiological resting period of 30 min and were then informed about their role in the experiment (observer vs. target). Targets were aware of being observed during their performance, although they did not know by whom. While partner dyads were separated before starting the resting period, stranger dyads never interacted throughout the experiment. We controlled for confounding sources of firsthand stress in the observers by signing them a document guaranteeing that they would not be subjected to the TSST themselves. Forty-five minutes after arrival, targets were provided with the test instructions. Stress induction started 50 min after arrival. Subsequent to the stress phase, participants rested for 60 min (Fig. 1A and B).

In Study 1 (Leipzig), observation modality was manipulated. In Study 2 (Dresden), observer sex was varied. Familiarity was manipulated in both studies: In Leipzig, each target was paired with one observer (either partner or stranger) per testing session. In Dresden, the consistently applied virtual observation modality (video transmission) allowed pairing of each target with two observers per session (a partner and a stranger observing in separate rooms). All other factors were rigorously held constant between testing locations. This unique multi-centered and multi-study design established replicability of the occurrence of empathic stress and the influence of its modulatory factors (see Supplementary Table for an overview).

2.3. Stress induction

We applied the TSST (Kirschbaum et al., 1993; Kudielka et al., 2007), which, compared to other social-evaluative laboratory stressors, provokes the most reliable physiological stress responses (Dickerson and Kemeny, 2004). In short, after a 5-min preparatory anticipation phase, the TSST requires the participant to give an audio- and video-taped mock job talk (5 min) and engage in difficult mental arithmetic (5 min) while being probed and evaluated by a committee of two “behavioral analysts”.

2.4. Physiological measures

2.4.1. Salivary cortisol and alpha-amylase
Cortisol and alpha-amylase data were log-transformed to account for non-normal distribution and concentration-dependent variance due to HPA-axis dynamics, immunoassay interference and measurement error (Miller and Plessow, 2013). We then calculated the increase from the baseline (−10 min) to the average peak measurement values (+20 min for cortisol; +10 min for alpha-amylase). Given a strong negative correlation between baseline values and change scores, the latter were adjusted for levels at baseline (Benjamin, 1963) by extracting the standardized change score residuals from a regression model that was fitted to the data of all participants. For the heart rate data, change scores from the arithmetic mean of the 5-min baseline to the arithmetic mean of the 10-min stress phase were calculated.

2.4.2. Heart rate
Heart rate was derived from a continuous RR-interval tachogram recorded with a POLAR RS800sd running computer (POLAR Electro, Finland, OY) and analyzed with the Kubios HRV software. Data was collected for a 5-min baseline between 15 and 10 min prior to stressor onset and during the 10-min stress phase (Fig. 1B).

2.5. Trait and state empathy measures

Observers completed the 16-item German version (Saarbrücker Persönlichkeitsfragebogen; Paulus, 2009) of Davis’ Interpersonal Reactivity Index (IRI; Davis, 1983) tapping four aspects of empathy (fantasy, empathic concern, perspective taking and personal distress). Given meta-analytic evidence from imaging studies showing that state measures of empathy may be more sensitive to the experimental manipulations than trait measures (Lamm et al., 2011), we included the Emotional Response Scale (ERS; Batson et al., 1997) assessing situational empathy immediately after TSST termination. The ERS uses 20 emotional adjectives to gauge acute empathic concern and personal distress.

2.6. Statistical analysis

2.6.1. Data preparation
Cortisol and alpha-amylase data were log-transformed to account for non-normal distribution and concentration-dependent variance due to HPA-axis dynamics, immunoassay interference and measurement error (Miller and Plessow, 2013). We then calculated the increase from the baseline (−10 min) to the average peak measurement values (+20 min for cortisol; +10 min for alpha-amylase). Given a strong negative correlation between baseline values and change scores, the latter were adjusted for levels at baseline (Benjamin, 1963) by extracting the standardized change score residuals from a regression model that was fitted to the data of all participants. For the heart rate data, change scores from the arithmetic mean of the 5-min baseline to the arithmetic mean of the 10-min stress phase were calculated.

2.6.2. Descriptives of firsthand and empathic stress
Stress research (Miller et al., 2013) defines a significant physiological stress response by an average cortisol peak of at least 1.5 nmol/l over baseline (Fig. 1B). Given that a significant increase in the targets’ cortisol levels constitutes a prerequisite for empathic stress to arise in the first place, we initially examined the number of targets reaching this criterion of physiological significance. To provide a similar estimate of the actual physiological significance of empathic stress responses in the observer group, responder rates were
calculated for the entire observer sample and the relevant subgroups.

2.6.3. Empathic stress and modulatory factors
In an initial control analysis aiming to uncover systematic differences between testing locations, we compared firsthand cortisol stress responses of all targets and empathic cortisol stress responses in the subgroup of observers that was equally recruited in Leipzig and Dresden (female partners in the video condition). Targets’ and observers’ change scores were entered as dependent variables into two one-way independent ANOVAs with the between-subjects factor “location”.

Linear mixed-effects models using restricted maximum likelihood (REML) estimates were tested to examine the hypothesized two components of empathic stress: vicarious stress and stress resonance. The models included three potential modulating factors: familiarity between observer and target (partners vs. strangers), modality of observation (real-life vs. virtual) and observer sex (female vs. male). Similarly for cortisol, alpha-amylase and heart rate data, observers’ baseline-to-peak change scores (ΔJobserver) were entered as dependent variable into each model. As predictors, targets’ change scores (ΔTarget), familiarity, observation modality, observer sex and the interactions between the targets’ change scores and potential modulators (ΔTarget* familiarity, ΔTarget*observation modality, ΔTarget*sex) were entered. In order to control for potential differences between testing sessions and locations (Leipzig vs. Dresden), random effects were estimated as intercept variation between sessions and laboratories. Vicarious stress, operationalized as being independent of the targets’ stress levels, was expected to manifest as a significant main effect of familiarity, observation modality or observer sex (i.e., any effect that is independent of ΔTarget). Stress resonance was expected to manifest as a significant slope of the regression line (i.e., a main effect of or any interaction effect involving ΔTarget). Model fit was quantified by the likelihood-based coefficient of determination $R^2$. We used Nakagawa and Schielzeth (2013) method for obtaining marginal $R^2$ from linear mixed-effects models which assesses the variance explained only by the fixed (not the random) factors.

2.6.4. Interindividual differences in state and trait empathy
We calculated correlation analyses to test whether interindividual differences in trait (IRI) and state (ERS) empathy modulated the degree of empathic stress. For vicarious stress, the observers’ cortisol responses were adjusted for the targets’ cortisol responses by extracting the observers’ standardized change score residuals from a regression model. This was done because, based on our hypothesis, vicarious stress should be independent of the targets’ cortisol levels. Then, bivariate correlations between the observers’ adjusted cortisol responses and their IRI and ERS scores were calculated. To examine the influence of trait and state empathy on stress resonance, the interaction terms of the targets’ cortisol responses with each of the questionnaire

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**Figure 2** Rates of observers responding with physiologically significant cortisol increases after passively watching a target undergo the Trier Social Stress Test (TST; Kirschbaum et al., 1993; Kudielka et al., 2007). (A) In the entire observer sample ($n = 211$), (B) grouped by familiarity (partners: $n = 111$; strangers: $n = 100$), (C) grouped by observation modality (real-life: $n = 50$; virtual: $n = 161$) and (D) grouped by observer sex (female: $n = 149$; male: $n = 62$).
scores were calculated and correlated with the observers’ cortisol responses. It was not necessary to adjust for the targets’ cortisol levels here because we expected an association between observers’ and targets’ cortisol responses in stress resonance. These analyses were repeated for alpha-amylase and heart rate data.

3. Results

The original sample size of 211 observers was reduced to 206 for alpha-amylase and to 163 for heart rate data due to an insufficient quantity of sampled saliva and technical problems with the heart rate registration devices. All 211 observers displayed valid cortisol data. The Supplementary Table shows the distribution of participants per laboratory and experimental conditions.

3.1. Descriptives of firsthand and empathic stress

As initial reliability check, we verified whether the targets’ stress response compared with previous TSST studies. With 117 out of 151 targets (77.5%) exhibiting an at least two-fold increase in cortisol levels from baseline, we range well within the typical TSST responder rate of 70–85% (Kudielka et al., 2007). 144 out of 151 targets (95%) reached the criterion of physiological significance defined as increase of at least 1.5 nmol/l over baseline (Miller et al., 2013) (Fig. 1B).

A total of 54 out of 211 observers displayed a physiological significant increase in cortisol levels (Δcortisol) after passively watching a target undergo the TSST corresponding to an overall empathic stress responder rate of 26%. Grouping observers by our relevant categories revealed the following responder rates: Partners: 44/111 (40%), strangers: 10/100 (10%), Δstress marker \(\chi^2(1, n = 111) = 24.27, p < .001\); real-life observation modality: 15/50 (30%), virtual observation modality: 39/161 (24%), \(\chi^2(1, n = 111) = .67, p > .40\); women: 40/149 (27%) and men: 14/62 (23%), \(\chi^2(1, n = 211) = .42, p > .50\) (Fig. 2A–D illustrate the observers’ responder rates overall and in the relevant categories).

3.2. Empathic stress and modulatory factors

An initial control analysis showed no differences in cortisol stress responses in Leipzig and Dresden for all the targets (\(F_{1, 150} = 0.25, p > .60\)) and the observer subgroup of female partners in the video condition that was equally tested in both locations (\(F_{1, 45} = 0.77, p > .30\)).

The statistical significance of empathic stress was tested using linear mixed-effects models. For cortisol, a significant main effect of Δtarget indicated the presence of stress resonance. Regarding the potential modulatory factors, a main effect of familiarity and a marginal interaction of Δtarget and familiarity point toward both stronger vicarious stress and stronger stress resonance in partners than strangers.

**Table 1** Parameter estimates and fit statistics for the cortisol, alpha-amylase and heart rate data in the linear mixed-effects model analyses.

<table>
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<th>Cortisol</th>
<th>Alpha-amylase</th>
<th>Heart rate</th>
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<tr>
<td>Intercept</td>
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<tr>
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<tr>
<td>Relationship</td>
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<td>–0.383***</td>
<td>–0.747</td>
</tr>
<tr>
<td>Modality</td>
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<td>–0.405*</td>
<td>–6.217*</td>
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<tr>
<td>Sex</td>
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<td>–0.006</td>
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<td>ΔStress marker × relationship</td>
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\(p < .001\), \(p < .01\), \(p < .05\).

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**Figure 3** Modulatory factors of cortisol stress resonance. (A) The calculated linear mixed-effects model showed higher stress resonance in emotionally close observer-target dyads (\(r = 0.242^*\)) such that observers’ and targets’ (\(n = 111\) for both) cortisol responses were positively correlated in the partner condition. There was no association between observers’ and targets’ (\(n = 100\) for both) cortisol responses in the stranger condition. (B) Indicating higher stress resonance given the real-life representation of the stressful situation (\(r = 0.427^{**}\)), observers’ and targets’ (\(n = 50\) for both) cortisol responses were positively correlated in the one-way mirror condition. There was no association between observers’ and targets’ (\(n = 161\) for both) cortisol responses in the virtual observation condition. (C) Observer sex had no significant influence stress resonance (0.115).
Table 2  Correlation coefficients between individual trait and state empathy and vicarious stress and stress resonance for cortisol, alpha-amylase and heart rate, respectively.

<table>
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<tr>
<th>Trait empathy</th>
<th>Vicarious stress (^a)</th>
<th>Stress resonance (^b)</th>
<th>Vicarious arousal (^a)</th>
<th>Arousal resonance (^b)</th>
<th>Vicarious arousal (^a)</th>
<th>Arousal resonance (^b)</th>
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<td>Empathic concern</td>
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<td>0.159 (^*)</td>
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<td>–0.032</td>
<td>0.126</td>
<td>–0.057</td>
<td>0.015</td>
<td>–0.002</td>
<td>–0.085</td>
</tr>
<tr>
<td>Perspective taking</td>
<td>0.106</td>
<td>0.160 (^*)</td>
<td>–0.134</td>
<td>0.018</td>
<td>0.052</td>
<td>–0.099</td>
</tr>
<tr>
<td>Fantasy</td>
<td>0.029</td>
<td>0.162 (^*)</td>
<td>–0.056</td>
<td>0.043</td>
<td>0.043</td>
<td>–0.066</td>
</tr>
<tr>
<td>State empathy (^d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empathic concern</td>
<td>0.218 (^{**})</td>
<td>0.176 (^*)</td>
<td>0.114</td>
<td>0.008</td>
<td>0.103</td>
<td>–0.065</td>
</tr>
<tr>
<td>Personal distress</td>
<td>0.075</td>
<td>0.184 (^{**})</td>
<td>–0.028</td>
<td>0.027</td>
<td>0.019</td>
<td>–0.069</td>
</tr>
</tbody>
</table>

\(\text{\(^a\) Observers’ responses adjusted for targets’ responses.}\)
\(\text{\(^b\) Observers’ unadjusted responses and the interaction terms of the targets’ responses.}\)
\(\text{\(^c\) Interpersonal Reactivity Index (IRI; Davis, 1983)/Saarbrücker Persönlichkeitsfragebogen (Paulus, 2009).}\)
\(\text{\(^d\) Emotional Response Scale (ERS; Batson et al., 1997).}\)
\(^*\) \(p \leq .01.\)
\(^{**}\) \(p \leq .05.\)

An interaction of \(\Delta\text{target}\) and observation modality indicates stronger stress resonance in the real-life than the virtual observation condition. No main effect of observation modality and thus no evidence for an impact of this factor on vicarious stress was found. Furthermore, there was no indication for an impact of observer sex on empathic stress, since neither the main effect of observer sex nor the interaction of \(\Delta\text{target}\) and observer sex reached significance (Table 1 left column; Fig. 3A–C).

The sympathetic markers only partially mirrored the cortisol results. We found a main effect of observation modality for both alpha-amylase and heart rate indicating higher vicarious arousal in the real-life than the virtual observation condition. Familiarity affected only alpha-amylase with higher vicarious arousal in partners than strangers. However, there was no evidence for arousal resonance since neither a main effect of nor an interaction involving \(\Delta\text{target}\) was revealed. Observer sex again had no effect on empathic stress (Table 1 middle and right columns).

3.3. Interindividual differences in state and trait empathy

Table 2 (left column) shows the correlation coefficients of the cortisol data with the observers’ trait (IRI) and state (ERS) empathy scores. For vicarious stress, a positive association with state empathic concern was found. For stress resonance, results show positive correlations with trait and state empathic concern, trait perspective taking, fantasy and state personal distress. Regarding the sympathetic measures, there were no significant correlations of vicarious arousal or arousal resonance with trait or state empathy scores (Table 2 center and right columns).

4. Discussion

We conducted a large-scale multi-center and -study project testing whether we could find evidence for true empathic stress permeating to the level of endocrine activation. Our results reveal that full-blown stress responses including HPA-axis and SNS activation can indeed be elicited by the mere observation of an individual undergoing psychosocial stress. In total, 54 out of 211 observers (26%) showed a physiologically (not just statistically) significant increase in cortisol levels. This finding is particularly remarkable considering that studies frequently experience difficulties in inducing firsthand cortisol stress responses to begin with (Dickerson and Kemeny, 2004). Importantly, and in contrast to a previous study attempting to measure the physiological resonance of stress in the actively engaged TSST committee members (Buchanan et al., 2012), our observers were entirely passive witnesses of the stressful situation. Moreover, they were aware of not having to undergo the TSST themselves. Possible sources of firsthand stress in the observers were hence controlled for.

Factoring in the influence of potential modulatory factors, mixed model analyses provided evidence for the existence of vicarious stress and stress resonance. As hypothesized, both components of empathic stress were more pronounced when observers were emotionally close to targets. The percentage of observers showing physiologically significant cortisol responses increased from 10% in strangers to 40% in partners. Furthermore, empathic stress was stronger in the real-life representation of the stressful situation. Whereas 24% of the observers exhibited physiologically significant cortisol increases in the video condition, this percentage increased to 30% when directly witnessing the stressful situation through a one-way mirror. Interestingly, sex had no significant influence on either component of empathic stress.

The result of more pronounced empathic stress in partners than strangers is in line with previous research highlighting the importance of a contextual approach to empathy. Alongside other characteristics of the observer-target relationship such as the affective link (Singer et al., 2006), familiarity was repeatedly shown to modulate the amount of empathy in a given situation (Cialdini et al., 1997; de Vignemont and Singer, 2006; Hein and Singer, 2008). Regardless of the higher
empathic stress in partners, however, strangers also exhibited physiologically significant cortisol increases following the observation of firsthand stress. Emotional closeness thus represents a facilitator but not a necessary condition for the occurrence of empathic stress. In everyday life, we mostly encounter people with whom we have some form of emotionally relevant relationship. As far as it is possible to predict real-life behavior from laboratory findings, the percentage of individuals experiencing empathic stress on the level of a physiologically significant cortisol response in everyday stressful settings may therefore range between 10 and 40%. It is important to note that by studying romantically attached couples, factors that go beyond emotional closeness like attraction and intimacy may have been involved in empathic responding. Future research should explore how different forms of emotional closeness (e.g., friendship, motherhood) and, inversely, negative emotions like resentment and aversion differentially influence the empathic stress response.

The stronger stress resonance in the real-life than the virtual observation modality suggests that the real-life representation of the stressful situation contains the multifaceted information useful to discern the target’s full stress experience. Alternatively, it would have been conceivable that observing a close-up video of the target’s face makes for the stronger stimulus given the increased resolution of transmitted information (e.g., blushing, sweating). However, such automatic facial changes are indicators of sympathetic arousal, while stress responses are more individual experiences primarily determined by internal evaluations (the most important of which being the perception of a situation as uncontrollable and self-threatening (Dickerson and Kemeny, 2004)). Again, note that regardless of the higher stress resonance in the real-life observation modality, physiologically significant cortisol increases also emerged in the virtual modality. We conclude that although stress resonance may be facilitated by direct exposure to others’ stress, its occurrence is not exclusive to real-life situations.

Sex had no impact on the occurrence of empathic stress. This finding contradicts the assumption of women being more empathic than men, as has been claimed in several studies (Hoffman, 1977; Eisenberg and Lennon, 1983; Baron-Cohen and Wheelwright, 2004; Rueckert and Naybar, 2008). On a critical note, these studies relied on self-report data which are highly prone to social desirability effects. As far as neuroimaging work is concerned, no sex differences in empathy have yet been reported. Precisely, in one study that did report sex effects, these referred to the modulation of empathy-related brain responses as a function of the targets’ perceived fairness (Singer et al., 2006). Our null finding thus adds to prior evidence suggesting that women and men do not differ in affective resonance if probed by implicit rather than self-report measures.

Self-reported empathy influenced both components of empathic stress on the endocrine level. In detail, the magnitude of vicarious stress was positively associated with state empathic concern only, while the magnitude of stress resonance was positively associated with trait and state empathic concern, trait perspective taking, fantasy and state personal distress. These results suggest that observers used affective and cognitive routes of social cognition to tune into the target’s state. The finding of an important role of interindividual differences in empathy measures matches previous imaging work showing correlations between these affective scales and empathy-related brain responses in the anterior insula cortex (Lamm et al., 2011). The fact that correlations were stronger for stress resonance than for vicarious stress supports our notion of vicarious stress as a comparatively self-focused state for which the ability to put oneself into another’s shoes is less relevant than for stress resonance.

Alpha-amylase and heart rate as markers of general arousal only partially mirrored the result pattern of the stress-specific hormone cortisol: While vicarious arousal was stronger when observers were emotionally close to targets (alpha-amylase) and in the real-life representation of the stressful situation (alpha-amylase and heart rate), there was no evidence for resonance between observers’ and targets’ alpha-amylase or heart rate responses. Again, sex had no influence on the occurrence of either component of empathic arousal. Also, no associations with trait or state empathy were found. The discrepant ability with which the hormonal and sympathetic markers depict empathic responses needs further investigation. One possible answer speaks to our previous interpretation that empathic stress responses are mediated by complex internal evaluations of the situation rather than by automatic symptoms of sympathetic arousal.

An open question for future research regards the transmission mechanisms of stress resonance: Via which pathways could the target’s state elicit a similar state in the observer down to the level of a hormonal response? Mimicry (i.e., the tendency to automatically synchronize affective expressions, vocalizations, postures and movements with those of another; Hatfield et al., 1994) represents a possible candidate. Based on the facial feedback hypothesis, Sonnby-Borgstrom (2002) proposed that mimicry enables us to automatically share and understand another’s emotions. Yet, the finding of less stress resonance in the close-up video condition while mimicry is particularly driven by facial expressions speaks against its seminal role in the occurrence of stress resonance. Rather than the detail, it seems to be the wealth of accessible information (e.g., tone of voice, facial expression) and the cognitive appraisal of the entire situation that leads to a fine-tuned empathic stress response in the observer.

It is a limitation of the current study that no standardized psychiatric interview was carried out in our participants. Although we did conduct a lengthy telephone interview screening for psychiatric disorders, we cannot rule out with certainty that some of the empathic stress responders suffered from a psychiatric disorder associated with an overactive HPA system.

While empathic stress is an established term in common parlance, sound empirical evidence for its occurrence was missing. Here, we could show that empathic stress is not just a subjective-psychological phenomenon but is indeed processed at the core of our physiological stress system. Observers are prone to exhibit more empathic stress when emotionally close to a target and with real-life access to the stressful situation. However, empathic stress also occurs in a considerable percentage of total strangers and with virtual observation opportunity only. Accordingly, even seemingly detached observers of a broadcast on TV may be struck by empathic stress. The experience of empathic stress
does not necessarily have to be rated as negative. Being in
tune with another individual may have an adaptive evolu-
tionary purpose in that it allows gaining information and
potentially understanding of the other’s situation. To that
effect it has been shown that behavioral and affective
attunement between mother and child is associated with
more adaptive outcomes such as increased self-regulation
(Raver, 1996; Feldman et al., 1999), positive affect
(Kochanska et al., 1999) and language competencies
(Carpenter et al., 1998). The adaptive value of physiological
attunement, specifically in response to stress and beyond
the mother-child dyad, is less obvious. Given the function
of acute HPA-axis activation, i.e., replenishing the body’s
energy supplies and restoring homeostasis (Chrousos,
2009), it could however be argued that an empathic stress
response allows mobilizing the resources required to help
a distressed target. While such adaptive qualities may apply
to the occasional empathic stress response, we have to
bear in mind that long-term elevations of cortisol levels
may exert detrimental health effects (McEwen, 2000).
The potential negative consequences of prolonged empathic
stress in everyday life thus have to be rated as significant.
Certain groups like the family members of chronically
stressed individuals or caregivers are at increased risk to
suffer adverse health effects of empathic stress. Above
and beyond such risk groups, the constant stream of devas-
tating news that we are confronted with in the daily media
has the potential to compromise a significant range of
people. Future research should explore ways to circumvent
the adverse effects of empathic stress. A potential remedy
may lie in the practice of mindfulness and compassion
(Keltner and Goetz, 2007). In going beyond the excessive
sharing of negative affect that is linked to the feeling of
empathy, training compassion (defined as the feeling of
concern for the suffering of others associated with the
motivation to help) can foster positive affect and
strengthen the activation of brain networks implicated in
affiliation and reward (Klimecki et al., 2013a,b).

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Conflict of interest

All of the authors declare that they have no conflicts of
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Appendix A. Supplementary data

Supplementary material related to this article can be
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