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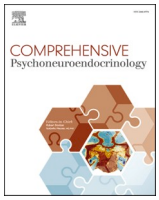

Biological sensitivity to adolescent-parent discrepancies in perceived parental warmth

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ABSTRACT

Introduction: Parenting behaviors are formative to the psychological development of young people; however, parent and adolescent perceptions of parenting are only moderately correlated with each other. Whereas discrepant perceptions may represent a normative process of deindividuation from caregivers in some adolescents, in others a discrepancy might predict psychological maladjustment. The biological sensitivity to context model provides a framework from which individual differences in development can be estimated in adolescents whose perceptions of parenting diverge from those of their parents.

Methods: At baseline we obtained diurnal cortisol samples from US adolescents (M = 13.37 years of age, SD = 1.06) as well as parents' and adolescents' ratings of parental warmth; we obtained adolescent-reported symptoms of psychopathology at baseline and again at follow-up two years later (N = 108, 57.5% female). We estimated waking cortisol, cortisol awakening response, and daytime cortisol slopes using piecewise regression models.

Results: Lower adolescent than parent ratings of parental warmth predicted increased externalizing symptoms at follow-up. Higher waking cortisol and steeper cortisol awakening response and daytime slopes predicted increased internalizing symptoms at follow-up. Further, discrepant ratings of parental warmth interacted with cortisol awakening response and daytime slopes such that greater discrepancies predicted greater increases in externalizing symptoms in adolescents with steeper cortisol slopes.

Conclusions: These findings indicate that steeper changes in cortisol production throughout the day index a greater sensitivity to perceived parental warmth. Lower adolescent than parent ratings of parental warmth may represent dysfunction in the parental relationship rather than a normative process of deindividuation in adolescents with steeper diurnal cortisol slopes.

1. Introduction

The parent-child relationship is among the most formative in young people's lives, guiding psychological development and providing scaffolding from which to build future social relationships. Unsurprisingly, parenting behaviors characterized by harshness, control, and neglect have been associated with rule breaking, aggression [1], and low self-esteem [2], whereas parental warmth, characterized by support and affection, has been linked to adaptive adolescent psychosocial functioning, including higher self-esteem, greater emotional stability [3], and adult psychosocial well-being [4]. Importantly, correlations between children's and parents' ratings of parenting behaviors are low to moderate [5,6]; thus, researchers have begun to consider reports of parenting behaviors from both informants in examining determinants psychosocial functioning (e.g., [7].

Adolescence is an important developmental period during which to assess discrepant ratings of parenting. As children transition to adolescence, their need for autonomy increases [8], for some youth outpacing the development of their self-regulatory processes [9]. Discrepant ratings of parenting behaviors by adolescents and their parents may be normative in the context of adolescent deindividuation [5,10]; indeed, successfully navigating conflict in the parent-adolescent relationship can lead to positive outcomes [10]. However, discrepant perceptions of parenting behaviors can also contribute to maladaptive outcomes [11].

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For example, higher parent than adolescent ratings of positive parenting behaviors have been linked to lower adolescent self-esteem [12]. Similarly, mutually discrepant ratings of parental affection have been found to be related to higher symptoms of anxiety and conduct disorder in adolescents [13]. Finally, higher parent-discrepant estimates of their knowledge about their adolescent's life, and lower parent-discrepant estimates of their reactions to their adolescent's anger have been associated with adolescents' externalizing symptoms [14,15].

Not all discrepant perceptions of parenting behaviors lead to problematic outcomes [10,16]. In fact, there may be individual differences in the effects of discrepant perceptions on adolescents' functioning. Biological sensitivity to context theory [17] posits that elevated activation of stress-related systems indexes a low threshold for the detection of environmental information [18]. Researchers have considered biological sensitivity to context in understanding individuals' sensitivity to a wide range of environments, including neighborhood density [19], pollution [20], and early life stress [21], documenting that greater sensitivity is related to more negative outcomes in the context of harsh conditions and to more positive outcomes in the context of favorable conditions.

Biological sensitivity to context has been found to moderate associations between parenting behaviors and negative child outcomes. For example [22], found that adolescents with lower skin conductance reactivity were more sensitive to the adverse effects of harsh parenting on externalizing symptoms. Further, stressful life events [23] and harsh parenting [24] predicted higher levels of internalizing and externalizing symptoms in youth with greater cortisol reactivity. Although promising, these findings are based on single-informant reports of parenting; researchers have not yet examined the relevance of biological sensitivity to context for understanding discrepancies between parents' and adolescents' perceptions of parenting behavior.

In this study we examined patterns of diurnal cortisol production as a moderator of the association between discordant ratings of parenting and adolescent psychopathology. Cortisol, a stress hormone, has been implicated in mood and arousal [25,26]. It is produced throughout the day, increasing upon waking with peak levels occurring around 30 min after waking (i.e., cortisol awakening response, CAR), and then gradually decreasing throughout the day (i.e., daytime slope). Variations in diurnal cortisol are posited to be related to individuals' ability to cope with psychosocial stress and their sensitivity to the environment. For example [27], found that blunted CAR predicted a quick rise in cortisol in response to a stressor and impaired recovery. Although researchers have linked diurnal cortisol with psychological functioning, it is not clear whether vulnerability to psychopathology is indexed by blunted or heightened slopes. Flatter diurnal cortisol slopes, reflecting blunted CAR or more elevated daytime slopes, have been associated with internalizing symptoms in children [28], with externalizing symptoms in children [29], and with antisocial traits in young adults [30]. Further, a meta-analysis of mostly adult studies found that flatter slopes were associated with poorer mental and physical health [31]. However, a larger CAR has also been associated with internalizing symptoms in young adolescents [32] and with overall mental distress in adolescents [33]. Further, diurnal cortisol has been posited to index sensitivity to the environment. For example, the associations between low socioeconomic status and adolescent social difficulties [34] and between parental corporal punishment and child anxiety symptoms [35] have been found to be stronger in youth with flatter CAR slopes. Conversely, the relation between neighborhood density and adolescent delinquency and aggression is stronger in participants with *steeper* CAR slopes [19]. Thus, it is unclear whether steeper or flatter diurnal cortisol slopes index sensitivity to context. Taking the developmental stage of study participants into consideration may help to explain discrepancies in the literature. In this context, puberty may be a particularly salient factor [36]; found that as adolescence age, their cortisol production increases and diurnal slopes become flatter. Further, adolescents in earlier stages of puberty who experienced early life stress have been found to have a smaller CAR, whereas adolescents in later pubertal stages who experienced early life stress have been found to have a larger CAR [37].

The present study was designed to examine diurnal cortisol as moderating the relation between discrepant adolescent-parent ratings of parental warmth and the development of internalizing and externalizing symptoms in adolescents over a two-year interval. We hypothesized that greater increases in adolescents' internalizing and externalizing symptoms will be predicted by lower adolescent-than parent-ratings of parental warmth and by flatter CAR and daytime cortisol slopes. We also tested whether waking cortisol, CAR, and daytime slopes moderate the association of discrepant ratings of parental warmth with change in internalizing and externalizing symptoms. We expected that in adolescents with flatter diurnal cortisol slopes, lower adolescent-than parent-ratings of parental warmth will be associated with higher internalizing and externalizing symptoms, whereas higher adolescent-than parent-ratings of parental warmth will be associated with fewer symptoms.

2. Methods

2.1. Participants

Participants were part of a larger ongoing longitudinal study of early life stress conducted in the San Francisco Bay Area. Participants were recruited via flyers and local media. Exclusion criteria for entry into the study were post-pubertal status based on Tanner staging [38], non-fluency in English, inability to undergo magnetic resonance imaging, and history of neurological disorder or major medical illness. Participants returned for follow-up assessments approximately every two years. All participants and their legal guardians gave informed assent and consent, respectively, and were compensated for their time. All study procedures were in accordance with the guidelines set forth by the Declaration of Helsinki and were approved by the Stanford University Institutional Review Board.

Participants in the present study were assessed twice, with approximately a two-year interval (M = 2.26 years; SD = 0.54). At baseline (June 2015-July 2019), 172 participants (55.7% female) completed the assessment (M age = 13.35 years; SD = 1.05), and at follow-up (February 2018-June 2021), 162 participants (58.5% female) completed the assessment (M age = 15.47 years, SD = 1.72, see Table 1 for additional demographic characteristics). At baseline, saliva samples were provided by 145 participants, of whom 138 provided complete information about the times the samples were collected. Thirty adolescents or parents had incomplete ratings of parenting behavior at baseline or incomplete data on internalizing and externalizing symptoms at baseline or follow-up. Thus, 108 participants had complete data available for all measures at both assessment points. Demographic characteristics of the sample at baseline and at follow-up are presented in Table 1. White participants were more likely (X^2 (1) = 8.77, p = .003) and Black participants were less likely (X^2 (1) = 5.00, p = .025) to complete the cortisol sampling data; there were no completion differences by other racial categories or in age, pubertal stage of development,

Table 1
Demographic characteristics.

	Baseline	Follow-up
Age (in years)	13.37 (1.06)	15.49 (1.71)
Tanner stage	3.48 (0.91)	4.33 (0.66)
Income-to-needs ratio	1.28 (0.55)	1.31 (0.53)
Sex (proportion female)	54.9%	57.5%
Race		
White	46.9%	43.1%
Black/African American	6.2%	8.4%
Hispanic	8.0%	7.8%
Asian	11.7%	13.2%
Biracial	22.2%	21.6%
Other	5.0%	5.9%

family income-to-needs ratio, internalizing symptoms, externalizing symptoms, or parental warmth discrepancy (all *ps* > .08). Participants who participated at baseline but not at follow-up were more likely to be at a later stage of pubertal development ($M_{no\ follow\text{-}up} = 3.87$, $M_{follow\text{-}up} = 3.42$, $t\ (161) = 2.25$, $p = .013$); there were no differences between those who did and who did not participate in the follow-up assessment in age, race, family income-to-needs ratio, internalizing symptoms, externalizing symptoms, or parental warmth discrepancy. Further, Little's test was not significant $X^2\ (123) = 141.30$, p = .124, indicating that data were missing at random.

2.2. Measures

2.2.1. Covariates

Participants reported on their age, sex, and race at baseline. Participants also completed the Tanner Staging questionnaire [39], an assessment of pubertal development of pubic hair and breasts/testes.

2.2.2. Cortisol

On two consecutive days at baseline, adolescents provided four saliva samples: upon waking (sample 1), 30 min later (sample 2), at 3:00 p.m. (sample 3), and at bedtime (sample 4). Samples were collected with SalivaBio Children's Swabs (Salimetrics, LLC) following in-person and written instructions that specified not to eat or drink prior to sample collection. Participants were provided a diary to record collection times and returned the samples to the lab at a subsequent study visit. Samples were stored at −20 °F until assayed with a high-sensitivity (0.004 g/dL) immunoassay kit from Immuno-Biological Laboratories Inc. (Hamburg, Germany; both intra- and inter-assay coefficients of variation (CV) for the kit ranged from 3 to 5%). To control for inter-assay error, samples were assayed together in large batches.

We had collected saliva samples in this study prior to the publication of the guidelines for cortisol awakening responses recommended by [40]; nevertheless, we do but closely adhere to these guidelines. Specifically, we collected samples only on weekdays, excluded inaccurate data with a margin of ± 5 min, instructed participants to avoid eating, drinking, or brushing teeth before sample collection, controlled for pubertal status and internalizing or externalizing symptoms concurrent with sample collection in analyses, used a dynamic measure of CAR increase rather than area under the curve with respect to ground, collected samples over two days, and report the associations between waking cortisol and CAR (Table 2). However, we did not use objective measures of time of sample collection. Consistent with field recommendations [41], at each sampling period we winsorized cortisol values that were >2 SD above the mean value of the sample to the 2-SD value. Samples collected at the same time of day were averaged across the two days. Across the two days of collection, corresponding time-of-day samples were correlated as follows: sample 1 r = 0.636, sample 2 r = 0.856, sample 3 r = 0.762, sample 4 r = 0.927. These values were entered into a piecewise regression model to estimate intercept (waking cortisol), cortisol awakening response, and daytime cortisol slope (see below for details).

2.2.3. Parenting

Concurrent with giving the saliva samples at baseline, parents and adolescents completed the 11-item Parenting Styles and Dimensions - Warmth questionnaire [42]. Adolescents were instructed to complete the questionnaire with respect to the parent or guardian who accompanied them to the assessment. For 95% of participants, this parent was their mother. This measure assesses the frequency with which the parent shows affection to and support for the adolescent, rated on a scale from 1 (*almost never*) to 5 (*very often*). Items were modified for the parent version, so that items like *My parent gives comfort and understanding when I am upset* were reworded to *I give my child comfort and understanding when they are upset*. There were no significant differences in adolescent- or parent-reported warmth as a function of the sex of the parent.

2.2.4. Symptoms

At both the baseline and follow-up assessments, adolescents completed the Youth Self Report (YSR) Scale [43] to report on their emotional and behavioral symptoms. The YSR has eight syndrome scales, of which the anxious/depressed, somatic complaints, and withdrawn scales comprise an internalizing score, and the aggressive behavior and rule-breaking scales comprise an externalizing score. We used T-scores adjusted for the adolescents' sex and age in the analyses. 16% of participants completed the follow-up assessment after the onset of the COVID-19 pandemic in March 2020. These participants completed the YSR remotely. Internalizing and externalizing symptoms were slightly (and nonsignificantly) higher in participants who completed the YSR during the pandemic than in participants who completed the YSR before the pandemic (internalizing p = .302, externalizing p = .120)

2.3. Data analysis

2.3.1. Cortisol slopes

To model the diurnal cortisol pattern, linear, quadratic, cubic, and piecewise mixed-effects regression models were estimated from cortisol samples averaged across the two-day collection period regressed on collection time of the sample. The cortisol values and sample times were entered into the regression analyses. The piecewise regression, which allows for simultaneous estimation of separate CAR and daytime slopes, was a better fit to the cortisol data based on lowest AIC value (see Fig. 1 for visualization). The waking cortisol value (intercept), cortisol awakening response (CAR, samples 1–2), and daytime slope (samples 2–4) were extracted from the model, which was estimated using the nmle package [44]. The month in which the sample was taken, the time between midnight and the first sample, and Tanner stage of pubertal development at baseline were all associated with the cortisol values and, therefore, were used to calculate standardized residuals for subsequent analyses. These analyses were conducted in RStudio (2022.07.1 build 554; Rstudio Team, 2022).

Table 2
Correlations among study variables.

	M(SD)	1	2	3	4	5	6	7	8	9	10
1. Parent-rated warmth	47.82 (5.11)	–									
2. Adolescent-rated warmth	43.22 (8.01)	.28**	–								
3. Warmth discrepancy	−0.03 (1.17)	−.59**	.61**	–							
4. Waking cortisol	0.00 (0.98)	−.02	−.13	−.08	–						
5. CAR slope	0.00 (0.98)	.001	.03	.03	.49**	–					
6. Daytime slope	0.00 (0.98)	−.01	.05	.02	−.84**	−.89**	–				
7. Internalizing Baseline	50.13 (11.91)	−.03	−.20*	−.14	−.08	.07	−.002	–			
8. Externalizing Baseline	46.66 (9.53)	.01	−.26**	−.22**	−.02	.07	−.03	.63**	–		
9. Internalizing Follow-up	55.14 (11.39)	.04	−.19*	−.15	.16	.20*	−.21*	.58**	.40**	–	
10. Externalizing Follow-up	50.97 (10.47)	.03	−.33**	−.27**	.09	.09	−.10	.40**	.64**	.49**	–

Note. CAR=Cortisol Awakening Response; Internalizing = internalizing symptoms on the YSR; Externalizing = externalizing symptoms on the YSR. **$p > .01$, *$p < .05$.

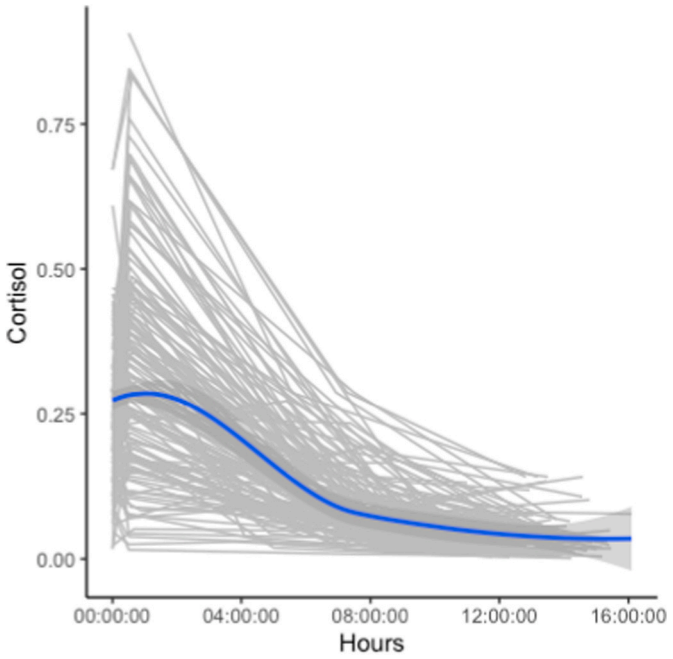

Fig. 1. Cortisol levels across the day in the whole sample.

2.3.2. Statistical models

We then conducted a series of regressions in PROCESS for R to predict changes in internalizing and externalizing symptoms. Regressions were conducted simultaneously for internalizing and externalizing symptoms, setting a common seed for bootstrap sampling. The use of a common seed is equivalent to correlating the outcome variables in order to take into account the non-independence of internalizing and externalizing symptoms and to minimize the number of regression analyses conducted.

Parent and adolescent ratings of parental warmth were mean centered; parent ratings were then subtracted from adolescent ratings to calculate a discrepancy score, in which a more negative score represents a higher rating of parental warmth from the parent than from the adolescent. The use of a difference score is the most commonly used method to model discrepancy in ratings [45]. Waking cortisol, CAR slope, and daytime slope were entered into separate linear regressions as moderators of the association between warmth discrepancy and symptoms. Baseline symptoms were entered into the regression analyses as a covariate to control for internalizing and externalizing symptoms separately, allowing us to model change in symptoms.

We used main effects of the discrepancy in ratings of parental warmth discrepancy and of cortisol values predicting internalizing and externalizing symptoms at follow-up, adjusted for baseline levels of symptoms, to test hypotheses 1 and 2; we added the interaction terms of discrepancies in warmth ratings and cortisol values to test hypothesis 3.

Finally, we conducted supplementary analyses to examine whether ratings of parental warmth by adolescents or parents, considered separately, predicted symptoms independently or in interaction with the cortisol metrics. Thus, we conducted separate regression models using adolescent- and parent-rated parental warmth as predictors of adolescent symptoms at follow-up with cortisol as a moderator and baseline symptoms as a covariate to estimate change in symptoms. Separate models were estimated for the three cortisol variables (i.e., waking, CAR, and daytime slopes) predicting internalizing and externalizing symptoms.

3. Results

3.1. Correlations among the primary variables

Correlations among the primary variables in this study are presented in Table 2. Adolescent-rated parental warmth was negatively associated with internalizing and externalizing symptoms at both baseline and follow-up; parent-rated parental warmth was not associated significantly with symptoms at either timepoint. Ratings of the degree of discrepancy between adolescents' and parents' ratings of parental warmth were also negatively associated with externalizing symptoms at baseline and follow-up (i.e., a greater discrepancy was associated with higher symptoms); however, the magnitude of the discrepancy in adolescent and parent ratings was not significantly associated with internalizing symptoms at either timepoint. Waking cortisol, CAR, and daytime cortisol slopes were not significantly associated with externalizing symptoms at either timepoint. Internalizing symptoms at follow-up were positively related to CAR slope and negatively related to daytime cortisol slope, indicating that individuals with more reactive diurnal cortisol slopes had higher levels of internalizing symptoms.

3.2. Are discrepant ratings of parental warmth associated with greater increases in internalizing and externalizing symptoms?

A main effect of parental warmth discrepancy at baseline predicted an increase in externalizing symptoms at follow-up (B = −1.93, 95% CI -3.17, −0.07, see Table 3), indicating that a greater discrepancy in parental warmth ratings (i.e., a more negative difference score) was associated with a greater increase in symptoms, providing support for Hypothesis 1. Parental warmth discrepancy was not significantly associated with a change in internalizing symptoms.

3.3. Are flatter CAR and daytime cortisol slopes associated with greater increases in internalizing and externalizing symptoms?

Main effects of waking cortisol, CAR slope, and daytime cortisol slope predicted increases in internalizing symptoms at follow-up (see Table 4). Higher waking cortisol (B = 2.94, 95% CI 0.98, 4.91), higher CAR slope (B = 2.14, 95% CI 0.23, 4.06), and lower daytime cortisol slope (B = −2.85, 95% CI -4.74, −0.96) were associated with a greater increase in internalizing symptoms, indicating that steeper, rather than flatter, slopes predicted greater increases in internalizing symptoms. Main effects of cortisol metrics did not predict change in externalizing symptoms.

Table 3
Warmth discrepancy predicting externalizing symptoms.

	B	SE	p	95% CI
Warmth Discordance	−1.85	0.63	.004	−3.10, −0.60
Waking Cortisol	0.69	0.75	.361	−0.80, 2.17
Baseline Externalizing	0.63	0.08	<.001	0.48, 0.79
Warmth * Waking	−0.97	0.56	.087	−2.09, 0.14
Warmth Discordance	−1.93	0.62	.003	−3.17, −0.70
Cortisol Awakening Response (CAR)	0.55	0.72	.221	−0.80, 2.79
Baseline Externalizing	0.61	0.81	<.001	0.45, 0.77
Discordance * CAR	−1.30	0.63	.044	−2.55, −0.03
Warmth Discordance	−1.89	0.62	.003	−3.12, −0.66
Daytime Slope	−0.72	0.72	.318	−2.15, 0.71
Baseline Externalizing	0.61	0.08	<.001	0.46, 0.77
Discordance * Daytime	1.22	0.57	.036	0.08, 2.36

Note. CAR=Cortisol Awakening Response; Internalizing = internalizing symptoms on the YSR; Externalizing = externalizing symptoms on the YSR.

Table 4
Warmth discrepancy predicting internalizing symptoms.

	B	SE	p	95% CI
Warmth Discordance	−0.46	0.83	.580	−2.11, 1.19
Waking Cortisol	2.94	0.99	.004	0.98, 4.91
Baseline Internalizing	0.55	0.08	<.001	0.38, 0.71
Warmth * Waking	−0.99	0.74	.189	−2.47, 0.49
Warmth Discordance	−0.80	0.84	.343	−2.47, 0.87
Cortisol Awakening Response (CAR)	2.14	0.97	.029	0.23, 4.06
Baseline Internalizing	0.51	0.08	<.001	0.34, 0.68
Warmth * CAR	−0.88	0.84	.304	−2.56, 0.81
Warmth Discordance	−0.65	0.82	.430	−2.29, 0.98
Daytime Slope	−2.85	0.95	.004	−4.74, −0.96
Baseline Internalizing	0.52	0.08	<.001	0.36, 0.68
Warmth * Daytime	1.03	0.76	.179	−0.48, 2.54

Note. CAR=Cortisol Awakening Response; Internalizing = internalizing symptoms on the YSR; Externalizing = externalizing symptoms on the YSR.

3.4. Does waking cortisol, CAR slope, and daytime cortisol slope moderate the association between discrepancy in ratings of parenting warmth and changes in internalizing and externalizing symptoms?

3.4.1. Waking cortisol

Warmth discrepancy did not interact with waking cortisol levels in predicting changes in internalizing (B = −0.99, 95% CI = −2.47, 0.49) or externalizing symptoms (B = −0.97, 95% CI = −2.09, 0.14).

3.4.2. CAR slope

CAR slope did not interact with discordance in warmth ratings in predicting changes in internalizing symptoms (B = −0.88, 95% CI = −2.56, 0.81), but did moderate the association between warmth discordance and changes in externalizing symptoms (see Table 3, Fig. 2; B = −1.30, 95% CI = −2.55, −0.03). Greater discordance at baseline predicted larger increases in externalizing symptoms for adolescents who had a larger (i.e., 1 SD above the mean, a steeper increase) CAR slope (B = −3.32, p < .001) compared with those who had a smaller (i.e., 1 SD below the mean) slope (B = −0.66, p = .45). Fig. S1 illustrates the diurnal cortisol slopes of participants with larger, smaller, and mean-level CAR slopes.

3.4.3. Daytime cortisol slope

Daytime cortisol slope did not interact with warmth discordance in predicting changes in internalizing symptoms (B = 1.03, 95% CI = −0.48, 2.54), but did moderate the association between warmth discordance and changes in externalizing symptoms (see Table 3, Fig. 2; B = 1.20, 95% CI = 0.08, 2.36). Greater discordance predicted larger increases in externalizing symptoms for adolescents with a more negative (i.e., 1 SD below the mean, a steeper decline) daytime slope (B = −3.19, p < .001) compared to those who had a flatter (i.e., 1 SD above the mean) slope (B = −0.69, p = .42). Fig. S1 illustrates the diurnal cortisol slopes of participants with larger, smaller, and mean-level daytime slopes.

3.5. Supplemental analyses

We conducted supplemental analyses using parent and adolescent ratings of parental warmth to test whether separate ratings of warmth interacted with cortisol values to predict internalizing and externalizing symptoms. Neither main effects nor interactions of either adolescent- or parent-rated parental warmth and waking cortisol, CAR, and daytime cortisol slopes significantly predicted internalizing or externalizing symptoms (see Tables S1 and S2).

4. Discussion

In this study we investigated the relation between parent-adolescent discrepancies in perceived parental warmth and the development of internalizing and externalizing symptoms, and whether patterns of diurnal cortisol (i.e., waking cortisol levels, CAR slopes, and daytime cortisol slopes) moderate these associations. We found that lower ratings of parental warmth by adolescents than by parents predicted increases in adolescents' externalizing symptoms, and that a more reactive pattern of diurnal cortisol (higher waking cortisol, larger CAR slopes, and more negative daytime slopes) predicted increases in their internalizing

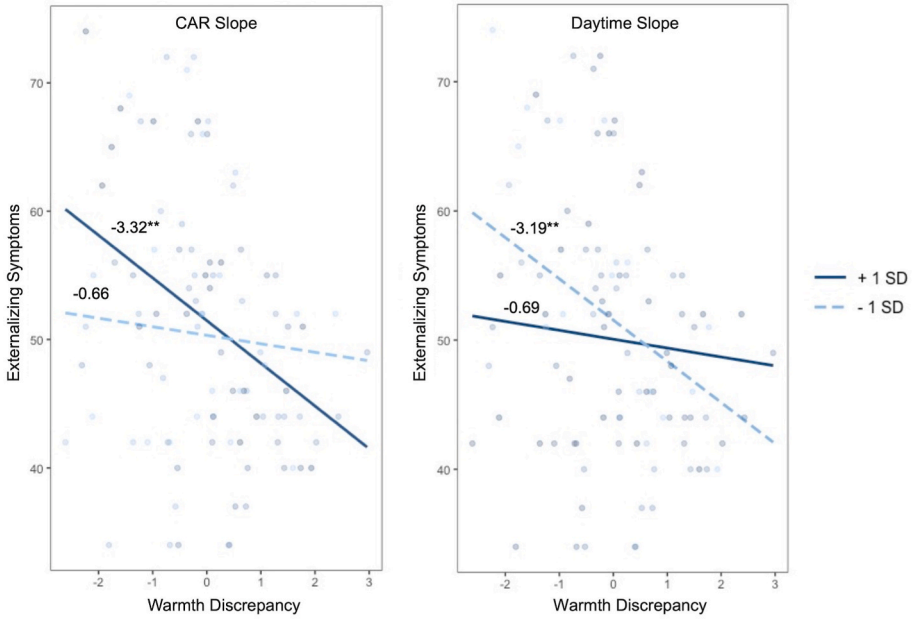

Fig. 2. (Left) Cortisol awakening response (CAR) moderates the association between adolescent-parent discrepancy in parental warmth rating at baseline and externalizing symptoms at follow-up. (Right) Daytime cortisol slope moderates the association between adolescent-parent discrepancy in parental warmth rating at baseline and externalizing symptoms at follow-up.

symptoms. We found further that, in adolescents with larger CAR slopes and more negative daytime cortisol slopes, lower adolescent than parent ratings of parental warmth were associated with greater increases in externalizing, but not in internalizing, symptoms.

Our finding that lower adolescent-than parent-rated parental warmth was associated with increases in externalizing symptoms extends the results of previous studies indicating that this directional discrepancy is associated with externalizing symptoms [1,13]; however, we did not find the same association with increases in internalizing symptoms. This was contrary to our hypothesis and to other literature identifying a relation between discrepant ratings of parental affection and anxiety symptoms [13]. This null finding is not unprecedented, however; Gustaferro et al. [12] similarly found no association between discrepant ratings of positive parenting and child internalizing symptoms. Further, other researchers have found bidirectional associations between positive parenting and child symptoms. For example, over three timepoints [46] found that externalizing symptoms predicted less positive parenting, which in turn predicted more externalizing symptoms; in contrast, internalizing symptoms were positively associated with positive parenting, which in turn predicted lower internalizing symptoms. These reciprocal associations may help to explain, in part, the stronger relation in the current study between externalizing symptoms and parent-adolescent discrepancies in ratings of parental warmth. Moreover, researchers should consider the informant who is reporting adolescent symptoms, given that adolescents may be reluctant to report instances of externalizing symptoms in particular. Notably, however, in a large cross-cultural study [47] found that levels of both internalizing and externalizing symptoms were higher when they were reported by adolescents than when they were reported by parents.

We also found that higher waking cortisol, larger CAR slopes, and more negative daytime slopes were related to greater increases in internalizing, but not in externalizing, symptoms. Whereas some investigators have linked flatter cortisol slopes with more severe externalizing [48] and internalizing symptoms [49], other researchers have found that steeper diurnal cortisol slopes are associated with more severe internalizing symptoms [48]. The association we found between steeper slopes and increases in internalizing symptoms supports the latter findings. Factors that may help to unravel these associations in future research may include participant age and sex (see [32] for findings by sex) the duration of elevated symptoms (i.e., chronic versus recently emerged), and genetic risk. For example, using a 5-variant additive serotoninergic multilocus genetic profile score [50], found that a steeper CAR was associated with emergence of depression in young adults only among those with a higher genetic profile score. This line of research may be a promising path forward in understanding the role of diurnal cortisol in the biological sensitivity to context framework.

Finally, we found that the association between discrepant adolescent-parent ratings of parental warmth and externalizing symptoms was stronger in adolescents who had steeper CAR and daytime slopes. This was contrary to our expectation that, consistent with previous findings (e.g. [34], flatter cortisol slopes would indicate increased sensitivity to context; it is important to note, however, that other investigators have identified *steeper* slopes as indicating risk in the context of adverse environments. For example, the relation between neighborhood density and symptoms of delinquency and aggression has been shown to be magnified in participants with steeper CAR slope [19]. Thus, steeper diurnal cortisol slopes may represent a heightened sensitivity to stressors, which in turn may increase adolescents' risk for developing psychopathology. Adolescents who experience greater changes in cortisol levels throughout the day may be more biologically sensitive to the perception that their parent lacks warmth. This heightened sensitivity may occur through anticipation of daily stressors or obstacles, which has been linked to a greater CAR (see review by [51]. Expectations about the occurrence of negative events, even when the events do not occur, have been found to be associated with greater negative affect [52], which could adversely affect perceptions of parental warmth. Further [53], found that higher diurnal cortisol secretion was related to impaired shifting of attentional control in emotionally demanding conditions, although they also found flatter daytime slopes, whereas we found that steeper CAR *and* daytime slopes were indicative of higher sensitivity. Interestingly, it appears in the current data that more negative daytime slopes in this sample are driven by higher CAR slopes, given the high negative correlation between CAR and daytime and slopes (Table 2) and the similarity in overall diurnal slopes of participants who were 1 standard deviation above the mean in CAR and participants who were 1 standard deviation below the mean in daytime slopes (Fig. S1).

In addition to expectations about parent behavior or sensitivity to relationship quality, steeper cortisol slopes may index a mismatch or discrepancy between adolescents' psychosocial needs and their parents' responsiveness or sensitivity to these needs. Of course, this may either be a cause or an effect of steeper cortisol slopes; we cannot determine directionality or causation in the current study. This formulation, however, could help to explain why adolescent ratings of parental warmth did not independently interact with diurnal cortisol to predict externalizing symptoms at follow-up; that is, although parents may demonstrate some warmth, they may be perceived as demonstrating enough warmth to meet the adolescents' needs.

Deindividuating from parental figures is a normative process in adolescence; in fact, within our sample lower adolescent-than parent-rated parental warmth did not significantly predict symptoms in participants who had flatter cortisol slopes (i.e., lower biological sensitivity). However, adolescents with steeper cortisol slopes may experience greater distress during this process of deindividuation when they perceive their parent as less warm than the parent does. In contrast, adolescents with steeper diurnal cortisol slopes who rated their parents as being warmer than the parents had rated themselves had the lowest levels of externalizing symptoms. This pattern of findings supports our hypotheses, based on the biological sensitivity to context framework, that participants who perceived their parents as warmer and were biologically sensitive would have fewer symptoms of psychopathology.

Discrepant ratings of parental warmth in which the adolescent perceptions are lower than the parent perceptions may reflect ineffective communication between parent and adolescent, or poor overall relationship quality. Indeed, more discrepant parent-adolescent ratings of conflict between parents and their adolescents have been related to a lack of open communication during conflict [54]. Further [15], found that parent overestimation of knowledge about the adolescent's life, which may index communication style, was related to externalizing symptoms. Thus, adolescents with steeper changes in cortisol, for whom we found was a stronger association between lower adolescent-than parent-rated parental warmth and externalizing symptoms, may have been more sensitive to the quality of their relationship with their parent. Notably, while adolescents who had steeper changes in cortisol production and a more negative view of parental warmth relative to their parent exhibited the highest increase in externalizing symptoms, adolescents with steeper cortisol slopes and more *positive* perceptions of parental warmth relative to their parents had the *lowest* increase in externalizing symptoms. Thus, consistent with the biological sensitivity to context model, diurnal cortisol production may index sensitivity to both positive and negative perceptions of caregiving.

We should note three limitations of this study. First, we asked participants to report on the parenting behaviors of the parent who accompanied them to the study assessment, who may not have been the parent who is closest to the participant. It is important to note, however, that a recent meta-analysis reported that parent gender was not a significant factor in understanding the effects of discrepancies between parents' and adolescents' ratings of caregiving [45]. It is likely, therefore, that our findings would be similar regardless of the parent who was rated. Second, although we did collect samples on two weekdays, we did not have an objective reporting measure of time of saliva sample collection, and we only collected one sample after waking to calculate

the CAR,. Third, we relied on single-informant measures of symptoms of adolescent psychopathology, which may be biased. Again, however, a large body of research supports the validity of adolescents' reports on the YSR (e.g. [55], thus minimizing concerns about the use of this measure.

Despite these limitations, our findings are important in demonstrating that steeper diurnal cortisol slopes were associated with increased sensitivity to the association between lower adolescent-than parent-rated parental warmth and the development of externalizing symptoms in adolescents over a two-year period. These findings may help researchers identify conditions under which discrepant perceptions of parenting by adolescents and their parents reflect a normative developmental process versus a problematic parent-adolescent relationship. In future work, we encourage researchers to consider including in their studies measures of parental sensitivity and the degree to which adolescents feel their psychosocial needs are met by parents in order to gain a better understanding of the mechanisms underlying the present findings.

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Ethics approval statement

All study procedures were approved by the Stanford University Institutional Review Board; all minor participants gave written informed assent and guardians gave written informed consent.

Data availability

Data will be made available upon request.

Declaration of competing interest

The authors have no conflicts of interest to report.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cpnec.2023.100211.

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