The Role of Stress Modality and Cognition in Neuroendocrine Reactivity during Childhood: Implications for Stress Reactivity Research

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Abstract

Background: Cortisol reactivity to laboratory tasks is usually interpreted as reflecting HPA axis functioning. However, stress reactivity is modulated by multiple cognitive and contextual processes, originating outside of the HPA axis itself, with significant implications for interpretation of task-induced cortisol reactivity. Yet, the way cognition and context interact to impact stress reactivity is poorly understood. One cognitive domain that has been linked to individual differences in neuroendocrine reactivity is Effortful Control (EC), the ability to voluntarily regulate behavior and attention. The current study investigated whether the impact of EC on cortisol reactivity is moderated by the type of stress.

Method: Participants (*n* = 64) were recruited from a longitudinal study. At age 3, EC was assessed using a standardized laboratory battery (EC-LabTask) and mother´s ratings on the Child Behavior Questionnaire (EC-CBQ-mother). At age 6, children were randomly assigned to one of two stress protocols to elicit frustration (*n* = 31) or fear (*n* = 33). Both tasks were administered following a 30 minute baseline period. Seventeen saliva samples were collected and cortisol reactivity was calculated.

Results: Controlling for differences in cortisol baseline levels, each EC measure significantly interacted with stress modality in predicting cortisol reactivity. Higher levels of EC-LabTask at age 3 significantly predicted <u>lower</u> cortisol reactivity in the frustration task at age 6, but marginally predicted <u>increased</u> stress reactivity in the fear task at age 6. This pattern was similar in the mother-rated measure of EC.

Discussion: Our study shows that individual differences in cortisol responses may be due to interactions between cognitive skills and stress type, which has implications for the interpretation of cortisol reactivity in stress protocols. For example, we found that HPA axis activation during frustration paradigms appears to be sensitive to individual differences in Effortful Control and thus may not directly reflect HPA axis sensitivity to the stressor applied.

Introduction

- Group and individual differences in cortisol response to laboratory tasks have conventionally been interpreted as reflecting HPA axis sensitivity to stress, presumably due to differences in receptor sensitivities within the axis itself.
- However, variations in cortisol responses to stress may not reflect intrinsic differences within the HPA axis per se, but instead reflect other, external factors (i.e., supra-hypothalamic) that modulate the HPA axis response to stress.
  - Stress reactivity is modulated by several factors such as cognition and stress modality, which might have significant implications for our interpretation of post-stress cortisol changes.
  - Yet, how cognition and context interact to impact stress reactivity is poorly understood.
- One cognitive domain that has been linked to individual differences in neuroendocrine reactivity is Effortful Control (EC).
  - EC is defined as individual differences in the ability to inhibit dominant responses and activate subdominant ones, to guide attention focusing and attention shifting and to voluntarily regulate behavior (Rothbart, 1989, 2005).
  - EC emerges with the development of the PFC during the preschool years (Ahadi, Rothbart, & Ye, 1993) and remains stable into later childhood (Kochanska, Coy, & Murray, 2001).
  - High EC has been associated with reduced cortisol reactivity to a competitive game in preschoolers (Donzella, Gunnar, Krueger, & Alwin, 2000).
- Different types of challenges (i.e., frustration vs. fear tasks) can produce different types of cortisol response profiles (Lopez-Duran et al., 2009). In this study, we attempted to determine whether high EC can reduce cortisol response to challenge in children regardless of stress context or whether EC effects might differ across challenge paradigms.

Discussion

- Our data suggest that individual differences in cortisol responses may be shaped by interactions between cognitive skills (EC) and type of stressor challenge.
- It is likely that different components of EC, such as emotion regulation or attention, interact with the stress context.
  - The social evaluative nature of the frustration task is likely activating the stress axis, involving slower, cognitive processes (indicated by later peak time).
    - EC might be modulating the response to the frustration task itself, likely acting via PFC inhibitory inputs to the hypothalamus.
    - Children with higher levels of EC may show increased capacity to inhibit the stress response, predicting reduced cortisol reactivity in response to the social evaluative task.
  - The fear task is likely activating the HPA axis by increasing anticipation of what is going to happen (indicated by earlier peak time).
    - However, only those children who are well engaged and attentive to the RA´s comments are going to be vulnerable to this anticipatory manipulation.
    - The positive association between attention focusing and both measures of EC may indicate differential engagement in the fear task: Children with higher levels of EC tend to show heightened cortisol release during the fear task due to their ability to attend to the task instructions relative to low EC children.
- The ability of EC to predict cortisol reactivity 3 years after its measurement is consistent with evidence that it marks a stable trait that develops during preschool years and remains stable into later childhood (Ahadi, Rothbart, & Ye, 1993; Kochanska, Coy, & Murray, 2001). It is also consistent with evidence that its emergence is linked to development of prefrontal cortex (Ahadi, Rothbart, & Ye, 1993), since PFC has inhibitory modulatory control over the HPA axis (Ulrich-Lai & Herman, 2009).
- This suggests that HPA axis reactivity to a laboratory challenge may be influenced by traits that reflect activity in supra-hypothalamic brain regions, rather than receptor sensitivities within the HPA axis itself. The findings suggest that the nature of these extra-hypothalamic effects may depend upon the stressor context being used.
- These types of effects and interactions need to be more thoroughly understood in order to meaningfully interpret cortisol reactivity data in stress protocols.

Methods

The community sample included 64 children who were recruited from families that previously participated in a longitudinal study.

Age 3: Laboratory and Subjective Assessment of EC

- A total score of the Kochanska's toddler-age behavioral battery (Kochanska et al., l996) served as a laboratory measure of EC (EC-LabTask).
- Mother´s ratings of child EC were obtained using an abbreviated version of the Child Behavior Questionnaire (EC-CBQmother; Ahadi et al., 1993).

Age 6: Stress Protocol

Children participated in a 90-min. laboratory session that included:

- 30-min. baseline period
- 3-min. stress task:
  Random assignment to Frustration or Fear condition
- 60-min. post-stress period (watching movies)

<u>Frustration condition</u> (*n* = 31)

- Children were offered a gift certificate if they would be able to open a Tupperware box while keeping their hands inside tennis socks.
- The research assistant (RA) demonstrated how easy the task was and made comments such as, "This is so easy even a baby can do it."
- The RA discreetly switched boxes and gave the child an identical looking box that was impossible to open.

<u>Fear condition</u> (*n* = 33)

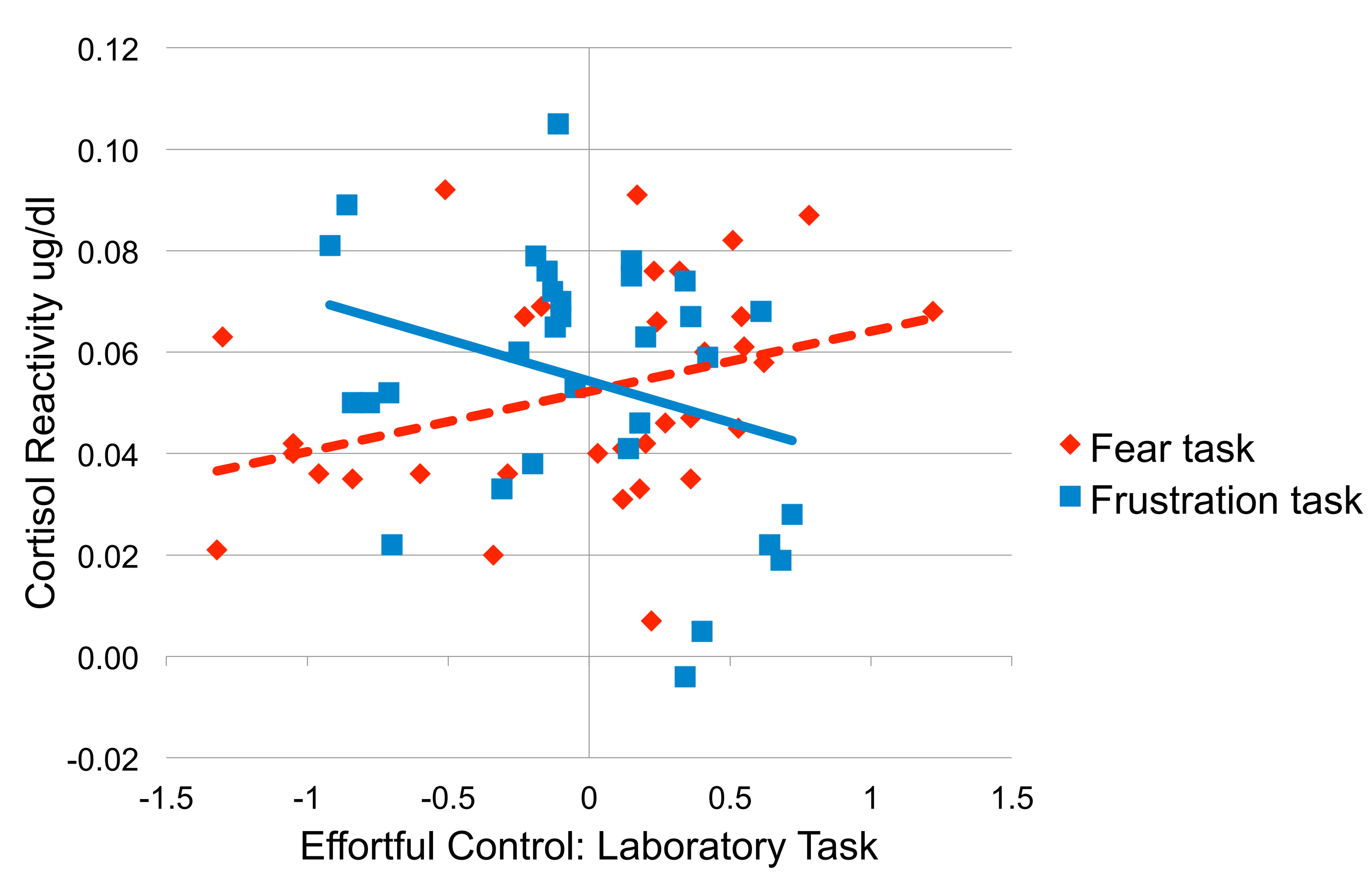
- Each child was taken into a semi-dark room containing a terrarium, which housed a realistic looking snake.
- While slowly approaching the terrarium, the RA made comments such as "I have something that I want to show you. It's inside that tank. Let's be quiet so it doesn't wake up."
- Suddenly, the RA takes the rubber snake out while simultaneously indicating that the snake was not real.

Cortisol Sampling.

- Baseline samples were taken at -30, -20, -10, and -5 minutes prior to stress.
- Samples were also obtained immediately after the stress condition (time 0), and at +5, +10, +15, +20, +25, +30, +35, +40, +45, +50, +55, and +60 minutes after the initiation of the stressor.
- Cortisol reactivity was calculated by subtracting baseline values from peak values after the initiation of the stressor.

Results

FIGURE 1. EC – as measured by the laboratory task – interacts with stress modality in predicting cortisol reactivity.



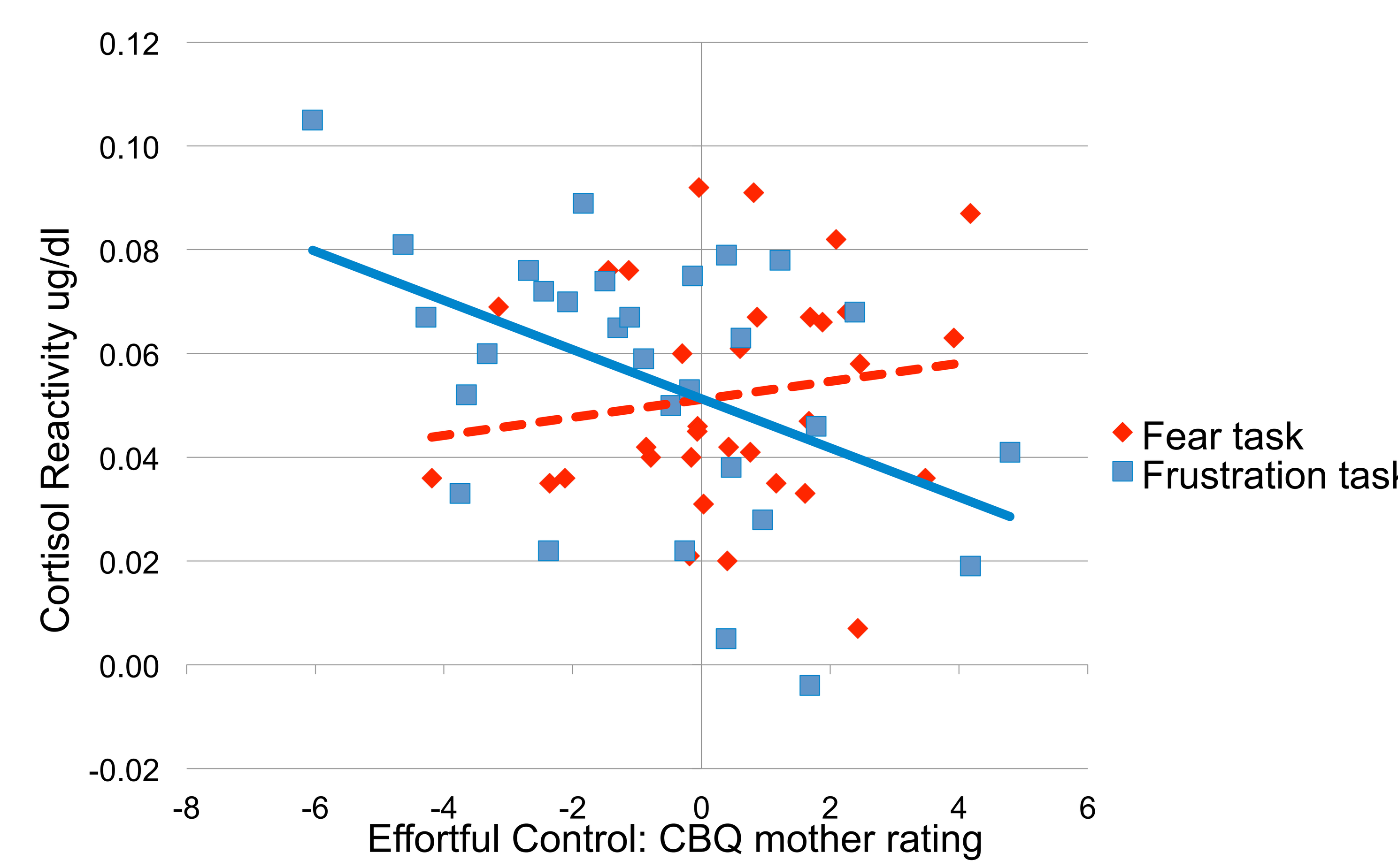
- The overall model was significant, R^2 = .17, $F(4, 59)$ = 3.04, p = .02.
- The interaction of EC (LabTask) and Stress Modality significantly predicted cortisol reactivity, B = .03, $t(59)$ = 2.88, p = .006, also see Figure 1.
  - In the frustration task, higher EC(LabTask) at age 3 significantly predicted lower cortisol reactivity at age 6, B = -.02, $t(59)$ = -2.15, p = .04.
  - In the fear task, higher EC(LabTask) at age 3 marginally predicted increased stress reactivity at age 6, B = .01, $t(59)$ = 1.94, p = .06.

Coefficients[a]

Model	Unstandardized Coefficients B	SE	t	Sig.
Intercept	.05	.004	13.82	.00
Cortisol Baseline Time 0	-.34	.16	2.10	.04
EC-LabTask	-.02	.01	-2.15	.04
Stress Modality	-.002	.005	.39	.70
Interaction EC-LabTask X Stress Modality	.03	.01	2.88	.01

a. Dependent Variable: Cortisol Reactivity (Peak-Baseline)

FIGURE 2. EC – as measured by mother´s ratings on the CBQ – interacts with stress modality in predicting cortisol reactivity.



- The overall model was significant, R^2 = .19, $F(4, 58)$ = 3.46, p = .01.
- The interaction of EC (CBQmother) and Stress Modality significantly predicted cortisol reactivity, B = .006, $t(58)$ = 2.48, p = .02, also see Figure 2.
  - In the frustration task, higher EC (CBQmother) at age 3 significantly predicted lower cortisol reactivity at age 6, B = -.01, $t(58)$ = -3.09, p = .003.
  - In the fear task, higher EC (CBQmother) at age 3 did not predict increased stress reactivity at age 6, B = .001, $t(58)$ = .70, p = .49.

Coefficients[a]

Model	Unstandardized Coefficients B	SE	t	Sig.
Intercept	.05	.004	12.33	.00
Cortisol Baseline Time 0	-.33	.17	2.02	.05
EC-CBQmother	-.01	.002	3.09	.003
Stress Modality	.000	.006	.07	.94
Interaction EC-CBQmother X Stress Modality	.006	.003	2.48	.02

a. Dependent Variable: Cortisol Reactivity (Peak-Baseline)

- There was a significant positive correlation between EC-LabTask and EC-CBQmother, $r(61)$ = .29, p = .02.
- Attention focusing, a subscale of the CBQmother was positively correlated with EC-LabTask, $r(61)$ = .34, p = .007 and EC-CBQmother, $r(61)$ = .80, p < .001.
- The frustration and fear tasks significantly differed in peak time, t(62) = -8.11, p < .001, with mean peak times at 45 min. and 25 min, respectively.

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No disclosures