Psychoneuroendocrinology 104 (2019) 195–202

Contents lists available at ScienceDirect

Psychoneuroendocrinology

journal homepage: www.elsevier.com/locate/psyneuen

Maternal childhood adversity, OXTR genotype and cognitive load impact on perceptual and behavioral responses to infant crying

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ARTICLE INFO

Keywords:
Infant crying
Childhood adversity
Oxytocin receptor gene polymorphism
Cognitive load
Parenting

ABSTRACT

The crying of infants elicits aversive feelings and poses a risk for child abuse. Maternal childhood maltreatment can have negative parenting ability consequences and interact with the oxytocin receptor (OXTR) single nucleotide polymorphism (rs53576) to predict maternal response to infant distress stimuli. Recent studies have highlighted the importance of individual vulnerability differences to situational cognitive load in parenting situations. The current study, in which 124 mothers participated in a standardized infant vocalization paradigm, examined three-way interaction on subjective empathy, behavior intention, and handgrip force response to a crying infant. Participants were asked to squeeze a handgrip dynamometer at maximal and half strength while memorizing a meaningless alphabet syllable as the cognitive load manipulation. Significant interactions were also observed between OXTR rs53576, childhood adversity, and cognitive load when predicting excessive force and harsh response intention on hearing a crying infant. These findings suggested that, as the G allele carriers of OXTR rs53576 appear to be susceptible to the effects of severe childhood adversity, inter- and intra-individual approaches are needed when assessing maternal responses to infant stimuli.

1. Introduction

As infant crying is a significant signal to parents, it motivates parents to care for them (Soltis, 2004). The sensitive response to crying can predict the healthy development of the child (Bell and Ainsworth, 1972; Fearon et al., 2010). However, as infant crying has been seen to be an aversive stimuli, it can sometimes lead to physical abuse and neglect (Reijneveld et al., 2004). Therefore, it is necessary to address the individual differences that can affect negative responses to infant crying, and identify the psychological and physiological mechanisms that influence such negative maternal responses to crying infants. This is important to prevent child abuse and suggest adaptive parenting interventions.

Maternal childhood experiences have been found to impact psychophysiological responses to infant crying (Casanova et al., 1994). Studies that have assessed the effects of maternal childhood experiences on parenting attitudes have found that people who had received strict parenting were more likely to adopt an abusive parenting style in their relationships with their children (Sroufe, 2005). What this means is that having negative parenting experiences during childhood negatively influences a parent's capacity to regulate their emotions and behavior, which could be a problem when reacting to their children's emotions. However, even though some previous research has found that maternal childhood trauma can have long-term negative consequences for the processing of infant signals, Isumi and Fujiwara (2016) found from a large population questionnaire study that maternal childhood adversity, such as physical abuse, psychological abuse, or neglect, was not associated with shaking or smothering 4-month old infants when they cried. These inconsistencies suggest that there are individual differences in terms of the proneness and/or plasticity to childhood traumatic experiences.

To elucidate the individual differences associated with the effects of maternal childhood adversity, in this study, we focused on a gene-by-environment approach (Nomura and Nomura, 2006) which have indicated that the oxytocin system is shaped by early experiences and especially by parent–infant interactions (Ross and Young, 2009). Toepfer et al. (2017) emphasized the oxytocin system as a key role of intergenerational transmission of childhood maltreatment. The neuropeptide oxytocin plays a key role in reproduction, parturition, and nursing. Recent research has revealed that oxytocin affects social behavior such as affiliation, empathy, trust, and coping with stress. Maternal oxytocin levels have been positively associated with sensitive caregiving behavior (Feldman and Bakermans-Kranenburg, 2017). The oxytocin receptor gene polymorphism (OXTR) has been found to be

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https://doi.org/10.1016/j.psyneuen.2019.03.005
Received 11 October 2018; Received in revised form 18 January 2019; Accepted 5 March 2019

related to biological oxytocin level differences, as it regulates the availability of the oxytocin system (Nishizato et al., 2017). OXTR rs53576, which involves a silent G to A substitution in the third intronic region, has been one of the most studied single nucleotide polymorphisms for the oxytocin receptor gene (Toepfer et al., 2017). A recent meta-analysis reported that G allele homozygotes were found to generate a higher general sociality than A-allele carriers (Li et al., 2015) and that individuals with the rs53576 A allele tended to have lower empathy, higher physiological and dispositional stress reactivity (Rodrigues et al., 2009), and lower levels of sensitive parenting toward their toddlers (Bakermans-Kranenburg and van IJzendoorn, 2008; Klahr et al., 2015). However, Michalska et al. (2014) found contradictory result that A allele of OXTR rs53576 contributes to positive parenting. The inconsistent findings also require consideration of gene x environment interaction.

A series of recent studies suggested that in early life stages, rs53576 might reflect a sensitivity to social environment (Bradley et al., 2011), leading sometimes to mental health or personality issues in adulthood (Belsky et al., 2009; Bradley et al., 2011, 2013). With increasing childhood traumas, the GG homozygotes in rs53576, but not the A-allele carriers, have been found to cause strong gray matter reduction in the bilateral ventral striatum (Dannlowski et al., 2016). Therefore, variations in OXTR rs53576 may indicate a different susceptibility to the long-term effects of childhood experiences on the neural and social phenotypes, which seems to suggest that people with the OXTR G allele, who have suffered childhood trauma, may have trouble processing an infant's negative emotional stimuli and as a result fail to regulate their own emotions. Then, the first objective of this study was to investigate whether the interactions between maternal childhood adversity on excessive handgrip force while listening to an infant crying are moderated by OXTR polymorphism.

This study also addresses the susceptibility of the Environment x Gene to situational load. A recent study revealed that when there is a high cognitive load, people find it difficult to feel empathy or intention to care for a crying infant (Hiraoka and Nomura, 2016). Recognizing infant's emotional cues and providing adaptive caregiving requires the ability to regulate emotions (Rilling, 2013); however, the cognitive resources associated with emotional regulation are limited. Additionally, people who have low trait emotional regulation skills have been found to be susceptible to situational cognitive stress (Dvorak and Simons, 2009) and that individuals with the OXTR G allele and childhood adversity experiences have lower emotional regulation skills (Bradley et al., 2011). All of this suggest that caregivers with childhood trauma experiences and the plastic OXTR G allele are highly vulnerable to situational cognitive loads because those individuals have low capacity to control their emotion (Bradley et al., 2011). Although dispositional emotion regulation was not treated in this study as a mediator because examining the mediation effect would cause a single preliminary research to become very complicated, this experimental work provides one of the first investigations into how maternal childhood adversity and OXTR polymorphism influence the susceptibility to situational load predicting responses to an infant's negative expressions.

This study examined the effects of maternal childhood trauma, OXTR, and situational cognitive load and effect of interactions of these variables on subjective state empathy, intentions in response to cry, and handgrip force while hearing an infant crying. These indicators have been used in previous research and they reflect attitudes to infant crying or the risk of child abuse (e.g., Buisman et al., 2018; Compier-de Block et al., 2015; Lin and McFatter, 2012). It is possible that the process of the occurrence of subjective and behavioral responses would differ. For example, the personal childhood experiences of parents only affected handgrip force, while they did not significantly influence subjective ratings (Buisman et al., 2018). However, previous research revealed that OXTR x childhood experience predict dispositional empathy (McDonald et al., 2016), and the interaction could predict parental empathy for infant distress. It is unclear whether the independent variables and these interaction effects of the current study would specifically affect each indicator. Hence, the current study used these indicators to examine the effects of childhood adversity, OXTR, and the situational cognitive load on response to infant crying from diversified standpoints.

The following hypotheses were developed for this study;

H1. Negative childhood experiences cause a negative response to infant crying (Buisman et al., 2018). OXTR G allele would pose greater risks for mothers who experienced more negative childhood trauma (Bradley et al., 2011).

H2. Mothers would show negative response to infant crying under high cognitive load situation (Hiraoka and Nomura, 2016, 2017). Especially, mothers who have negative childhood experience and OXTR G allele would be vulnerable to cognitive load.

2. Method

2.1. Participants

The experiment included the participation of 124 mothers. We restricted the sex of participants to only include mothers because sex could confound the outcome. The response to infant crying may differ between the sexes (Seifritz et al., 2003; Swain et al., 2014) and mothers suffer more from the stress of crying children and, thus, evince more risk of child abuse (Ministry of Health, Labor and Welfare, 2017). The mean age of the participants was 35.32 ± 4.22 years and all participants were engaged in rearing infants or toddlers (Mean age 2.54 ± 1.79). 58 participants (47%) were primiparous and 66 participants (53%) were multiparous mothers. This study was approved by the ethics review board of the Graduate School of Education, Kyoto University and was carried out in accordance with the relevant guidelines. All participants provided written consent to participate.

2.2. Procedure

During the lab visits, each participant completed the computer tasks and questionnaires. Buccal mucosa cell samples were collected for the genotyping.

2.3. Measures

2.3.1. Behavioral responses to infant crying

Excessive handgrip force has been widely used to measure maladaptive responses to infant crying. For example, Compier-de Block et al. (2015) recruited mothers who had committed child abuse and found that they had excessive handgrip force compared to the control mothers when listening to an infant's emotional vocalization. This result suggested that the lack of handgrip force modulation seems to reflect the emotion dysregulation and risk for child abuse. As practice, the participants were asked to squeeze the dynamometer with their preferred hand at full power and a half power several times in rotation. During the practice period, the participants could check their performance on a monitor. The monitor was then turned away and participants asked to squeeze the dynamometer three times in succession with the second squeeze being at half the strength of the first squeeze. The performance was checked in real time.

In the main task, the participants were prompted to squeeze the handgrip dynamometer eight times at full and half strength while listening to infant crying sounds or tone, respectively.

The recordings of the spontaneously crying infant were recorded from a male infant aged seven months, from which two 2 min sound files were extracted. The mean fundamental frequency was 413.60 ± 6.72 Hz. The sound was used in prior research (Hiraoka and Nomura, 2016, 2017). The tones, which were at the same fundamental

frequency as the infant crying stimulus, were used to control the sound. The tones were created and edited using Audacity 2.0.634 and the acoustic analysis performed using Praat 5.4.0435. The procedure of using one voice and the time of two minutes were based on extant research that has utilized the handgrip task (e.g. Buisman et al., 2018; Compier-de Block et al., 2015).

The sound stimuli were presented through loudspeakers, with the crying infant and the tone sound being presented for two minutes x four times and with half being under a high cognitive load condition and the other half being under a low cognitive load condition. As in previous studies (Buisman et al., 2018; Compier-de Block et al., 2015), the grip strength modulation was calculated by dividing the half-strength squeeze intensity by the full-strength squeeze intensity; therefore, scores over 0.50 indicated excessive force for the half-strength squeeze attempt. The higher the score of handgrip force are, the lesser the participants could regulate their emotion. The intervening time between the full- and half-strength prompts was 2 s and the time between the half-strength and the subsequent full-strength prompt was 25 s. The dynamometer (model TSD121C) weighed 315 g and was 185 mm in length, 42 mm wide, and 30 mm thick, with an isometric range from 0 kg to 100 kg. The squeeze intensities (in kg) were transferred directly from the dynamometer to the Acknowledge software program (version 3.8; Biopac Systems, 2004).

To manipulate the cognitive load while the handgrip was being squeezed, a meaningless English alphabet string to be memorized was presented on a display for 3 s before the presentation of each sound. The procedure and materials of cognitive load manipulation were used in previous research (Hiraoka and Nomura, 2016, 2017; Maehara and Saito, 2013). Subsequent to the sound presentation, participants were asked to recall the memorized meaningless English alphabet string using the keyboard. The number of letters given in the task (e.g. two or eight) was divided by the number of letters participants correctly recalled, which is the obtained memory task score. For example, if participants remembered every character correctly, the score was marked as 1; if participants reported an error even in first letter, the score obtained was 0; and if participants answered the half of the letters accurately, a score of 0.5 was given. The cognitive load was manipulated within the subjects and between the blocks. There were four blocks separated by a 2 min rest. Half the blocks were low load condition and the other half were high load. The order for the high- and low-load blocks was counterbalanced between the participants. Intraclass correlation coefficient (ICC) of handgrip force through the entirety of the trials was .57 ($p < .01$), the ICC of low load condition was .63 ($p < .01$), and the ICC of high cognitive load condition was .60 ($p < .01$). These results evidenced that the handgrip response was stable for each participant throughout the whole experiment and for each condition.

2.3.2. Subjective rating

2.3.2.1. Empathy rating. Subjective ratings (empathy and response intention) in response to the crying infant were rated at the conclusion of each infant crying sound. As empathic emotions, empathic concern (EC) and personal distress (PD) were rated. Although both emotions are aspects of emotional empathy, while EC, aroused by infant crying, has been shown to positively predict intention to provide care (Lin and McFatter, 2012), PD has been shown to predict intention to perpetrate neglect (Hiraoka and Nomura, 2016). Each EC and PD had one item (EC: "I felt concerned for the baby"; PD: "The longer I listened to the crying, the more helpless and frustrated I felt"). Each response was given on a five-point Likert scale ranging from 1 (Does not describe me well) to 5 (Describes me very well).

2.3.2.2. Intention rating. There were six questionnaire items concerning the intention in response to infant crying based on previous research (Hiraoka and Nomura, 2016; Lin and McFatter, 2012): "I felt like picking up the baby", "I felt like changing the diaper or bottle feeding the baby", "I want to slap the baby", "I want to shake the baby strongly", "I want to leave the baby alone", and "I want to go to another room". All responses were given on a five-point Likert scale ranging from 1 (Does not describe me well) to 5 (Describes me very well). The six items of intention ratings were subjected to an exploratory factor analysis using maximum likelihood estimation with Promax rotation. Result showed two subscale scores (CFI = .968, RMSEA = .088): Intention of caregiving response ("I felt like picking up the baby", "I felt like changing the diaper or bottle feeding the baby", and "I want to leave the baby alone" (reverse); $\omega = .68$); and Intention of harsh response ("I want to slap the baby", "I want to shake the baby strongly", and "I want to go to another room"; $\omega = .69$). All ICCs of subjective ratings (empathic concern, personal distress, intention of caregiving response, and intention of harsh response) of the sum of the trials, of the low load condition, and of the high load condition were significant (ICCs > .62, ps < .001). These results evidenced that the subjective ratings were stable for each participant throughout the whole experiment and for each condition.

2.3.3. Questionnaire

The Childhood Trauma Questionnaire (CTQ; Bernstein et al., 2003) was used to assess the participants history of child sexual, physical, emotional abuse, physical neglect, and emotional neglect. The questionnaire had 28 items, with answers being given on a Likert type scale ranging from 1 (Never True) to 5 (Very Often True). The ω coefficient was .92. The number of participants who experienced more than the median levels for each category was listed as seven for emotional abuse, zero for sexual abuse, zero for physical neglect, one for physical abuse, and sixteen for emotional neglect. Although most participants did not rate above the median score, we consider the effect of childhood experience not to be dichotomous but spectrum. Hence, we used averaged scores following a prior study (Buisman et al., 2018).

The Japanese language version of the Balanced Inventory of Desirable Responding (Paulhus, 1991; translated by Tani, 2008) was used to measure the tendency to rate answers according to social desirability. The questionnaire had 24 items, and participants were required to provide ratings using scales ranging from 1 (completely disagree) to 7 (completely agree). The ω coefficient was .83.

2.4. Genotyping

Genomic DNA was extracted by oral swab using Catch-All Collection Swabs (Epicenter). Subsequently, the DNA was extracted using the QIAamp DNA Mini Kit (Qiagen). The 260/280 Absolute of all samples were between 1.8–2.0. The rs53576 genotyping was performed using the TaqMan SNP genotyping assays (AppliedBiosystems).

The PCR was carried out from a total volume of 2.5 µl genomicDNA, 12.5 µl TaqMan universal PCR master mix (AppliedBiosystems), 0.62 µl TaqMan SNP Genotyping Assays, and 9.38 µl ultra-pure water. After a pre-reading of 30 s at 60∘C and holding for 10 min at 95∘C, 50 cycles consisting of 15 s at 92∘C and 1.5 min at 60∘C annealing temperatures were performed. The primer was labeled as follow [VIC/FAM]; AAAG GTGTACGGGACATGCCCGAGG [A/G] TCCTCAGTCCCACAGAAACAG GGAG.

The genotyping revealed that the number of OXTR AA carriers = 49, OXTR AG = 57, and OXTR GG = 18, with the genotype frequencies being within the Hardy–Weinberg equilibrium ($\chi^2 = 0.09$, $p = .77$). Based on previous research findings, that individuals carrying one or both copies of the rs53576 G allele appeared to be more sensitive to the developmental environment than those carrying both copies of the A allele (Bradley et al., 2011, 2013), we coded the genetic variables as a two-level variable (GG and AG vs. AA).

2.5. Statistical analysis

Before the main analyses, differences in the score of memory task between the high load condition and low load condition was analyzed

using two-way repeated measure of the analysis of variance. Then, multilevel correlation was tested the between handgrip force, subjective empathy ratings and intention ratings.

To examine the current hypotheses, we conducted multiple regression analyses with mixed effect model because all variables were measured multiple times and were assumed to have a hierarchical structure. The handgrip force, empathic ratings (empathic concern and personal distress), and intention ratings (caregiving or harsh response) were dependent variables in each model and CTQ, OXTR, cognitive load, and sound (only in handgrip model) were considered to be independent variables. The mothers' age, children's age, the number of children, and social desirability (only in empathy ratings and intention ratings) were entered as control variables. The mothers' age, children's age, CTQ, and social desirability scores were centered using the grand mean. The number of children, OXTR, cognitive load, and sound were dummy coded (the number of children: one = −0.5, two or more = 0.5; OXTR: AA = −0.5, AG/GG = 0.5; cognitive load: low load = −0.5, high load = 0.5; sound: tone = −0.5, infant crying = 0.5). The intercepts and slopes for the individual level and stimulus level were entered as random effects. We employed the step down method for the choice of acceptable models using the step function of the lmerTest package (Kuznetsova et al., 2015) because there were many variables and we attempted to avoid repeated analysis. In this function, non-significant fixed and random effects were reverse eliminated with $\alpha = 0.05$. We used the restricted maximum likelihood for the estimation of each model. The lmerTest package (Kuznetsova et al., 2015) in R 3.1.2 (R Core Team, 2014) was used to multilevel multiple regression analyses, and the rmcorr package (Bakdash and Marusich, 2017) was used to conduct the multilevel correlation analyses. We applied Bonferroni correction to each conceptually independent dependent variable for the number of models (handgrip strength with no correction due to solely one model, state empathy with correction factor of two, and intention ratings with correction factor of two).

3. Result

3.1. Preliminary analyses

The GG/AG and AA carriers were not found to differ significantly in terms of the demographic characteristics and self-reported measures for the CTQ score and social desirability ($p_s > .22$).

As we employed within-participant manipulation of the cognitive load conditions, we conducted an analysis of variance to determine if order effects were present. Handgrip force and subjective rating scores were regarded to be dependent variables while condition (high load or low load), order (high load first or low load first), and the interaction between them were considered independent variables. The main effect of order, and its interaction with condition were not found to be significant ($Fs < 3.22$, $ps > .08$), indicating no effect of order on the results.

To verify the effect of cognitive load manipulation, A two-way repeated measure of the analysis of variance with cognitive load and sound condition as independent variable and memory task score as dependent variable was conducted. The number of letters given in the task (e.g. two or eight) was divided by the number of letters participants correctly recalled, which is the obtained memory task score. For example, if participants remembered every character correctly, the score was marked as 1; if participants reported an error even in first letter, the score obtained was 0; and if participants answered the half of the letters accurately, a score of 0.5 was given. If the manipulation of cognitive load was valid, compared to low load condition, the memory task score of high load condition would be lower. The result revealed that there were significant main effects for cognitive load (F (1, 123) = 1470.50, $p < .01$, $\eta_p^2 = .93$) and interaction (F (1, 123) = 5.29, $p = .02$, $\eta_p^2 = .04$), with a significantly greater decrease in scores (low load : M = .99 ± .004: high load : M = .41 ± .02, t (120) = 28.25, $p < .01$) being found for the high cognitive load condition. These results indicated that the memory task was significantly more difficult in the high cognitive load condition than the low cognitive load condition. The results also indicated that the memory task was significantly more difficult when the infant was crying compared to the tone sound (infant crying: M = .38 ± .01, tone: M = .43 ± .01, t (120) = 2.85, $p < .01$). These results were consistent with previous research that reported that participants had the least correct working memory task trials when hearing an infant crying than for other noises (Hechler et al., 2015).

Table 1
Multilevel correlations of handgrip force, empathic concern, personal distress, intention of caregiving response, and intention of harsh response.

		1	2	3	4	5
1	Handgrip force	**.74** **	.01	.16 *	−.10	.06
2	Empathic concern		**.71** **	.14 **	.17 **	−.09
3	Personal distress			**.63** **	−.09	.27 **
4	Intention of caregiving response				**.68** **	−.11
5	Intention of harsh response					**.77** **

p value was corrected by Holm's method.
* $p < .05$.
** $p < .01$.

We tested the multilevel correlation between handgrip force and each subjective rating, the results of which are shown in Table 1. Handgrip force was found to be positively correlated with personal distress ($r = .16$, $p = .03$).

3.2. Effects of CTQ, OXTR, and cognitive load on handgrip force

Multiple regression in multilevel modeling was conducted to examine the effects of the maternal CTQ score, OXTR, the cognitive load, and sound on handgrip force. The maternal age, the number of children, and the children age were included as the control variables. The intercepts and slopes for the individual level and stimulus level were entered as random effects.

The results for the multilevel multiple regression on handgrip force were presented in Table 2. The main effect of cognitive load was found to be significant ($b = .02$, $p = .02$), which meant that participants had gripped the handgrip dynamometer with excessive force during the high cognitive load condition. The three-way interaction between

Table 2
Cognitive load, OXTR, and childhood trauma experience on handgrip force to infant and tone sounds.

		Estimate	SE	P	
Fixed Effects					
	Intercept	0.59	0.01	.00	***
	Cognitive load	0.02	0.01	.02	*
	OXTR	−0.03	0.02	.13	
	CTQ	−0.01	0.03	.57	
	Cognitive load x OXTR	−0.01	0.01	.47	
	Cognitive load x CTQ	0.00	0.02	.79	
	OXTR x CTQ	0.09	0.05	.08	
	Cognitive load x OXTR x CTQ	0.06	0.03	.04	*
Random Effects					
Person Level	Intercept	0.02	0.12		
	Slope	0.00	0.06		
Stimulus Level	Intercept	0.00	0.01		
	Slope	0.00	0.10		

Note: CTQ Childhood Trauma Questionnaire; OXTR Oxytocin Receptor Gene Polymorphism.
* p < .05.
*** p < .001.

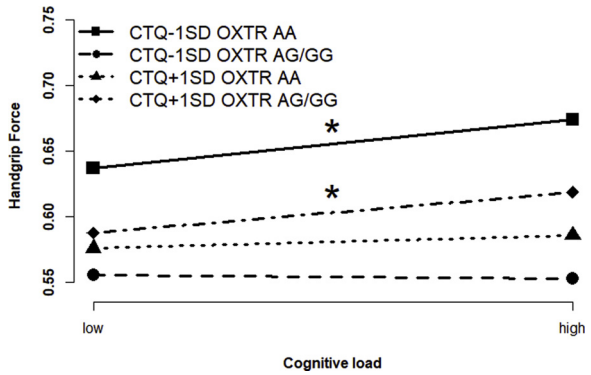

Fig. 1. Interaction between cognitive load, OXTR, and childhood trauma experience predicting handgrip force.

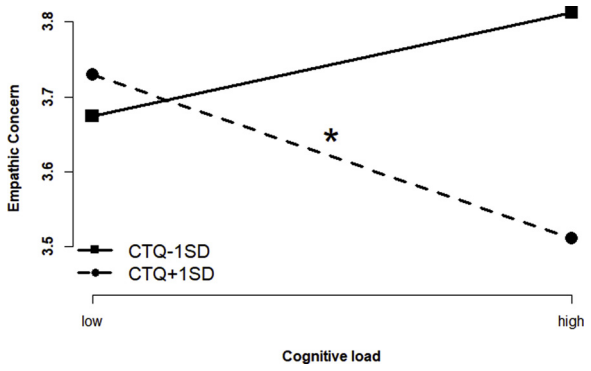

Fig. 2. Interaction between cognitive load and childhood trauma experience predicting empathic concern toward crying infant.

cognitive load, OXTR, and the CTQ score was also found to be significant (b = .06, p = .045). We conducted a simple slope analysis on the three-way interaction (Preacher et al., 2004), the results of which are shown in Fig. 1, in which it can be seen that the cognitive load only significantly increased the handgrip force in mothers with low CTQ and the OXTR AA allele (β = .04, p = .02) and those with high CTQ and the OXTR G allele (β = .03, p = .03).

3.3. Effects of the CTQ, OXTR, and cognitive load on empathic response

3.3.1. Empathic concern

The effect of the cognitive load, OXTR, and CTQ on empathic concern for the crying infant are shown in Table 3. As can be seen, the one-way interaction of CTQ and cognitive load was significant (β = -0.42, p_{cor} = .03). A simple slope analysis indicated that cognitive load negatively predicted empathic concern only in participants with high CTQ scores (β = − 0.22, p = .03; Fig. 2).

3.3.2. Personal distress

The cognitive load, OXTR, and childhood trauma experiences were assessed in terms of personal distress for the crying infant (Table 3). As can be seen, only the main effect of cognitive load was significant (β = 0.19, p_{cor} = .04). Personal distress increased in high load condition. No significant interactions predicting intention to personal distress were found.

Table 3
Cognitive load, OXTR, and childhood trauma experience on empathy ratings to infant crying.

Empathic Concern		Estimate	SE	$P_{corrected}$	
Fixed Effects					
	Intercept	3.68	0.11	0.00	***
	Cognitive load	−0.04	0.07	1.00	
	CTQ	−0.15	0.25	1.00	
	Cognitive load x CTQ	−0.42	0.17	0.02	*
Random Effects					
Person Level	Intercept	1.28	1.13		
	Slope	0.20	0.45		
Personal Distress					
Fixed Effects					
	Intercept	2.36	0.16	0.00	**
	Cognitive load	0.19	0.09	0.04	*
Random Effects					
Person Level	Intercept	1.02	1.01		
	Slope	0.54	0.73		
Stimulus Level	Intercept	0.03	0.18		

Note: CTQ Childhood Trauma Questionnaire; *OXTR* Oxytocin Receptor Gene Polymorphism.
* $p < .05$.
** $p < .01$.
*** $p < .001$; p value was corrected by Bonferroni's method with correction factor of two.

3.4. Effects of the CTQ, OXTR, and cognitive load on intention rating

3.4.1. Intention of caregiving response

The effects of cognitive load, OXTR and CTQ on intention of caregiving response were shown in Table 4. The main effect of cognitive load was significant (β = -0.13, p_{cor} = .02). The high cognitive load condition decreased the intention of providing care for crying baby.

3.4.2. Intention of harsh response

We assessed the effects of cognitive load, OXTR, and CTQ on the intention of harsh response (Table 4). The main effects of children's age, CTQ and OXTR were significant (the children's age: β = 0.04,

Table 4
Cognitive load, OXTR, and childhood trauma experience on intention ratings to infant crying.

Intention of caregiving response		Estimate	SE	$P_{corrected}$	
Fixed Effects					
	Intercept	4.34	0.07	0.00	***
	Cognitive load	−0.13	0.05	0.02	*
	CTQ	−0.26	0.13	0.09	
	OXTR	−0.22	0.11	0.09	
Random Effects					
Person Level	Intercept	0.38	0.62		
	Slope	0.19	0.44		
Stimulus Level	Intercept	0.00	0.05		
Intention of harsh parenting					
Fixed Effects					
	Intercept	1.22	0.04	0.00	***
	Chile age	0.04	0.02	0.04	*
	Cognitive load	0.02	0.02	0.60	
	CTQ	0.24	0.08	0.01	**
	OXTR	0.18	0.07	0.02	*
	Cognitive load x CTQ	0.09	0.05	0.19	
	Cognitive load x OXTR	0.07	0.04	0.27	
	CTQ x OXTR	0.35	0.15	0.04	*
	Cognitive load x CTQ x OXTR	0.25	0.10	0.02	*
Random Effects					
Person Level	Intercept	0.12	0.35		
	Slope	0.02	0.15		
Stimulus Level	Intercept	0.00	0.04		

Note: CTQ Childhood Trauma Questionnaire; *OXTR* Oxytocin Receptor Gene Polymorphism.
* $p < .05$.
** $p < .01$.
*** $p < .001$; p value was corrected by Bonferroni's method with correction factor of two.

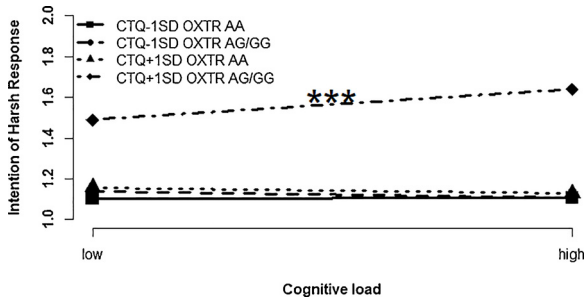

Fig. 3. Interaction between cognitive load, OXTR, and childhood trauma experience predicting intention of harsh response to crying infant.

p_{cor} = .04; CTQ: β = 0.24, p_{cor} < .01; OXTR: β = 0.18, p_{cor} = .02). Two-way interaction between CTQ and OXTR, and the three-way interaction between cognitive load, OXTR, and the CTQ score were also found to be significant (β = 0.35, p_{cor} = .04; β = 0.25, p_{cor} = .02). We conducted a simple slope analysis on the three-way interaction (Preacher et al., 2004). These results are shown in Fig. 3, which illustrates that the cognitive load only significantly increased the handgrip force in mothers with high CTQ and with the OXTR G allele (β = .14, p < .001).

4. Discussion

The current study demonstrated that childhood trauma, OXTR rs 53576, and situational load respectively interacted and predicted maternal emotional and behavioral responses in response to infant crying. To the best of our knowledge, the present study is the first to examine the interactions between maternal childhood adversity, OXTR, and situational cognitive load on handgrip force, empathic feelings, and behavioral intentions toward crying infant vocalizations. While some research showed that mothers who experienced childhood adversity have difficulties of emotion regulation while listening to infant crying (Buisman et al., 2018; Casanova et al., 1994), other research failed to find such relationship (Isumi and Fujiwara, 2016). The inconsistency would be because little research on response to infant crying investigated the genetic individual differences of susceptibility to early social environment. Those who had the OXTR G allele showed high susceptibility to their childhood environment and were observed to have greater emotional dysregulation (Bradley et al., 2011).

In consistence with the hypothesis, an interaction that predicted the harsh subjective intentions toward a crying infant was found between childhood trauma, OXTR, and cognitive load. Participants with the OXTR G allele and with higher CTQ scores reported a greater intention to perpetrate harsh parenting especially when they were under a condition of high cognitive load. A possible mechanism of this finding could be the ability to regulate emotion. Some previous studies have argued that emotion regulation by parents is very important (Crouch et al., 2018) and people with GG and who had experienced childhood trauma could suffer from emotion regulation difficulties (Bradley et al., 2011). These studies and the current findings suggest that people who have experienced childhood trauma and have the OXTR G allele are unable to regulate their emotions in an infant crying presentation and are motivated to relieve their own distress. A significant interaction between CTQ and cognitive load for empathic concern was also found, with people who reported higher CTQ showing a susceptibility to situational load. Because this was a preliminary study, it is not possible to provide a detailed discussion as to the reasons why there were differences in the interactions for the various variables in the current study; however, these findings have some conceptual and clinical implications. Future research should include trait emotion regulation skill in this model and examine whether it would mediate the effect of childhood adversity and OXTR.

The current result of handgrip force displayed the similar pattern of subjective intention. We found that while participants who reported a lower CTQ score and had OXTR AA allele were also vulnerable to situational load when hearing a crying infant, mothers with childhood adversity and OXTR G allele have emotional disabilities and difficulty with processing the infant crying; the difficulty may become prominent under high cognitive load consumed situation. The current finding that individuals with the OXTR AA allele also suffered from situational cognitive stress were in line with a previous study that found that individuals with the OXTR A allele were susceptible to experimentally induced stress (Rodrigues et al., 2009). This study is the first approach to investigate the interaction of inter-individual difference (gene polymorphism and childhood experience) and intra-individual difference (situational cognitive load) in parenting study. This approach would contribute to future parenting research about effects of exposure to infant emotional stimuli on parenting feeling and behavior from both theoretical and methodological perspectives.

Another finding was that a main effect for OXTR on harsh intention rating was found and the mothers with the OXTR G allele reported a higher intention to leave the crying baby alone. Although some previous studies have found that the presence of OXTR G had a positive effect on sensitive parenting (Bakermans-Kranenburg and van IJzendoorn, 2008; Klahr et al., 2015), Michalska et al. (2014) reported contradictory result that A allele of OXTR rs53576 contributes to positive parenting. Additionally, Elmadih et al. (2014, 2016) found that higher plasma oxytocin levels were related to insensitivity during mother-infant free play. The full effects of the oxytocin system on parenting are still unclear. While Nishizato et al. (2017) found that people with the OXTR G allele tended to have higher oxytocin levels, we did not develop a hypothesis on the main effects of OXTR as it was believed the phenotype was modulated by environmental factors. However, these findings indicate that there needs to be a more comprehensive investigation of OXTR and other environmental factors in future studies.

The multilevel correlation between the current variables showed that handgrip force related to personal distress. Previous studies have found that mothers at risk of parenting have difficulty regulating handgrip force during infant crying (Buisman et al., 2018; Crouch et al., 2008; Riem et al., 2016) and the current findings supported that handgrip force was related to a subjective rating of personal distress, which has been found to be a motivator for negative parenting such as neglect or physical abuse. However, the correlation coefficients were small, and the interpretation should be caution. Indeed, the pattern of main effects and interaction on behavioral response and subjective rating scores differ in the current study. It meant the behavioral and subjective indicators reflect different aspect. In future study we need to evaluate the relationship of these indicators with real behavior in free-parenting situation.

The present results should be considered in light of the study's limitations. First, this study relied on a retrospective self-report to measure the mothers' traumatic childhood experiences and was, therefore, unable to assess the actual trauma experiences, when they happened, or whether these were very early childhood experiences that are generally not encoded due to childhood amnesia. The recent study has shown that childhood experiences affect people differently depending on whether these were during a sensitive period of development (Schalinski et al., 2016). Additionally, as retrospective responses can be affected by current mental states or recent life experiences, future studies need to measure early negative experiences using unbiased methods. Second, our sample size was relatively limited compared to other gene x environmental studies, which may have restricted our ability to detect the effects. Additionally, we considered only one SNP (OXTR rs53576) as a moderator. The other OXTR SNPs such as rs232579 (Esposito et al., 2016) have been shown to moderate early childhood experiences in predicting the response to crying. We considered only rs53576 because of the sample size and the problem of statistical power. However, future studies should consider other OXTR

SNPs or other plasticity gene polymorphisms such as the 5-hydroxytryptamine-linked polymorphic region polymorphism or the dopamine receptor D4 (Belsky et al., 2009). Moreover, this study only recruited mothers and it is unclear whether the obtained result could extend to fathers. It is possible that men could present specific neural processing of crying stimuli and that they could exhibit different behavioral responses (Seifritz et al., 2003; Swain et al., 2014). Additionally, parenting by fathers independently predicts the cognitive development of the children (Tamis-LeMonda et al., 2004). Further studies that include both mothers and fathers to develop a full picture of the intergenerational transmission of parenting will be needed.

5. Conclusion

Parenting styles differ widely among mothers and can have a strong, longitudinal impact on their children (Fearon et al., 2010). In this study, it was revealed that maternal childhood trauma and OXTR interacted and predicted subjective feelings and a vulnerability to situational stress toward infant crying. Given that maternal responses to crying infants predict the child's attachment representations (Bell and Ainsworth, 1972; McElwain and Booth-Laforce, 2006), the maternal behaviour, empathy, and behavioral intention toward infant crying shown in the current study will influence the parenting style of the next generations. Therefore, these findings have significant implications for understanding the mechanisms shaping maladaptive parenting styles and the intergenerational transmission of child abuse.

Role of funding sources

This study was supported by grants from Kyoto University Design School. This funding source had no involvement in any stage of the study, data analysis and interpretation, or in the decision to publish this work.

Conflict of interest statement

The authors declare no conflict of interest.

Author contributions

Hiraoka designed and performed the research, conducted the statistical analysis and wrote and revised the manuscript; and Nomura designed and supervised the research and revised the manuscript.

Acknowledgments

We are grateful to Takeo Fujiwara for providing Japanese version of CTQ.

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