Authoritarian parenting predicts reduced electrocortical response to observed adolescent offspring rewards

Amanda R. Levinson, Brittany C. Speed, Brady Nelson, Jennifer N. Bress and Greg Hajcak

Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500, USA

Correspondence should be addressed to Amanda R. Levinson, B.S., Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500, USA.
E-mail: amanda.levinson@stonybrook.edu

Abstract

Parenting styles are robust predictors of offspring outcomes, yet little is known about their neural underpinnings. In this study, 44 parent-adolescent dyads (M_{age} of adolescent = 12.9) completed a laboratory guessing task while EEG was continuously recorded. In the task, each pair member received feedback about their own monetary wins and losses and also observed the monetary wins and losses of the other member of the pair. We examined the association between self-reported parenting style and parents' electrophysiological responses to watching their adolescent winning and losing money, dubbed the observational Reward Positivity (RewP) and observational feedback negativity (FN), respectively. Self-reported authoritarian parenting predicted reductions in parents' observational RewP but not FN. This predictive relationship remained after adjusting for sex of both participants, parents' responsiveness to their own wins, and parental psychopathology. 'Exploratory analyses found that permissive parenting was associated with a blunting of the adolescents' response to their parents' losses'. These findings suggest that parents' rapid neural responses to their child's successes may relate to the harsh parenting behaviors associated with authoritarian parenting.

Key words: reward positivity; EEG; parenting; adolescents

Introduction

Decades of research suggest that parenting style plays a critical role in child development (Darling and Steinberg, 1993; Borkowski *et al.*, 2002; Feller, 2014). Parenting styles are commonly conceptualized in terms of demandingness and responsiveness (Baumrind, 1971). From these two factors, four parenting styles have been delineated: authoritative, authoritarian, permissive and neglectful (Baumrind, 1971, 1991). Of particular interest for this study are authoritative and authoritarian parenting, the two most commonly employed parenting styles (Chan and Koo, 2011). 'Authoritative' parenting takes a 'firm but fair' approach, setting clear but rigorous expectations for the child (i.e. high demandingness), and encouraging bi-directional, democratic communication between parent and child (i.e. high responsiveness). 'Authoritarian'

parenting, sometimes colloquially referred to as the 'my way or the highway' approach, is the most discipline-oriented parenting style. Like authoritative parenting, authoritarian parenting involves high expectations for the child (i.e. high demandingness). In contrast, however, authoritarian parenting is less warm, and involves the expectation that the child should follow direction without debate or explanation (i.e. low responsiveness). Thus, authoritative and authoritarian parenting styles differ in terms of how much parents attend to offspring perspective—a difference that carries significant consequences.

Authoritative and authoritarian parenting are robust and often opposing predictors of offspring outcomes throughout development and across domains of functioning (i.e. social, academic, health etc.). Specifically, authoritative parenting predicts positive outcomes for offspring while authoritarian parenting

predicts negative outcomes (Deković and Janssens, 1992; Steinberg *et al.*, 1992; Kerr *et al.*, 2004; Underwood *et al.*, 2009; Chan and Koo, 2011; Rinaldi and Howe, 2012; Braza *et al.*, 2015). Parenting has even been linked to neural changes in offspring that may have clinical consequences. Higher levels of authoritarian parenting have been associated with children's increased electrocortical response to errors (the error-related negativity; Meyer *et al.*, 2014). Similarly, supportive and adaptive parenting behaviors have been shown to buffer children from a blunted electrocortical response to reward (i.e. the reward-related positivity or RewP) in those with a maternal history of depression (Kujawa *et al.*, 2014). These particular markers of electrocortical activity are clinically relevant because they are indicators of risk for anxiety and depression, respectively (Bress *et al.*, 2013; Proudfit *et al.*, 2013; Meyer *et al.*, 2015).

Parenting may be particularly important for adolescent offspring (Steinberg, 2001; Ungar, 2004), in a developmental period characterized by rapid increases in both anxiety and depression (Costello *et al.*, 2002; Green *et al.*, 2005; Thapar *et al.*, 2012). During adolescence, authoritative and authoritarian parenting continue to predict positive and negative outcomes, respectively (Steinberg, 2001; Hoskins, 2014), including in academic performance (Spera, 2005; Blondal and Adalbjarnardottir, 2009) and social functioning (Steinberg *et al.*, 2006; Underwood *et al.*, 2009). Furthermore, authoritarian parenting has been found to predict depression (Garber *et al.*, 1997) and anxiety (Wolfradt *et al.*, 2003) in adolescents, while authoritative parenting can have lasting protective effects for adolescents against psychopathology (DeVore and Ginsburg, 2005). In sum, parenting styles carry strong positive or negative consequences for the child. To better understand child development it is important to identify factors that undergird parenting styles.

A growing body of research has used event-related potentials (ERPs) to examine dyadic interactions in laboratory-based tasks in which participants watch others receive positive or negative feedback (Thoma *et al.*, 2015). This research builds on previous findings looking at a participant's ERP response to their gains (the Reward Positivity, or RewP) and losses (the feedback negativity or FN) in a laboratory guessing task, as well as the relative difference between the two. Principal components analysis has shown that the difference between the RewP and FN is driven by a fronto-central positivity at 300ms after gains but not losses (Foti and Hajcak, 2009). Furthermore, the magnitude of the difference score has been associated with neural and behavioral measures of reward processing (Carlson *et al.*, 2011; Bress and Hajcak, 2013). Thus, many researchers now calculate the difference score as the response to gains minus the response to losses (RewP minus FN), and to refer to this difference as ΔRewP, in order to highlight its relationship to reward processing (Holroyd *et al.*, 2008; Proudfit, 2015).

Interestingly, these same components (the FN, RewP and ΔRewP) can be elicited by observing the gains and losses of another person (Thoma and Bellebaum, 2012). The observational ΔRewP has been conceptualized as a marker of an empathic process (reviewed in Thoma and Bellebaum, 2012). In support of this conceptualization, the observational ΔRewP has been found to be increased in situations characterized by greater empathy, such as observing a friend compared with a stranger (Kang *et al.*, 2010), or when observing another human participant compared with a computer (Fukushima and Hiraki, 2009). Conversely, when a manipulation is used to reduce feelings of empathy for the observed, such as making a task competitive, the observational ΔRewP is reduced (Ma *et al.*, 2011). Finally, the most direct support for the link between the observational ΔRewP and

empathy comes from a study that found the amplitude of the observational ΔRewP was positively correlated with self-report scores of empathy (Fukushima and Hiraki, 2009; c.f. Bellebaum *et al.*, 2014). Interestingly, empathy scores did not correlate with the amplitude of ΔRewP to one's own monetary outcomes, suggesting that the responsiveness higher empathy is not simply linked to greater responsiveness to rewards in general, but rather linked specifically to responsiveness to the rewards of others. The observational ΔRewP, therefore, may be a useful measure in the study of the parent-offspring relationship.

In this study, we examined associations between parenting style and parents' ERPs to observing adolescents' monetary wins and losses in a laboratory guessing task. We also measured parents' ERPs to their own monetary outcomes in the same task. We hypothesized that greater authoritarian (i.e. harsh) parenting would be associated with a reduced observational ΔRewP while greater authoritative (i.e. firm but fair) parenting would be associated with an enhanced observational ΔRewP. Furthermore, we conducted additional analyses adjusting for participants' sex, psychopathology history and parents' ERPs to own outcomes, all of which may influence parents' observational ERPs (Hajcak *et al.*, 2006; Fukushima and Hiraki, 2009; Gu *et al.*, 2010; Marco-Pallarés *et al.*, 2010; Foti *et al.*, 2011a; Bress *et al.*, 2012, 2013; Thoma *et al.*, 2015).

Additional exploratory aims of the study were (i) to examine the relationship between parents' observational ΔRewP and permissive parenting, characterized by high parental support and few demands placed on the child; and (ii) to examine the relationship between parent measures (i.e. parenting styles and parents' ERPs) and offspring functioning, as measured by child ERPs and symptoms of anxiety.

Methods

Participants

The sample included 44 dyads of adolescents and a biological parent recruited from a larger investigation of the impact of puberty on neural measures of reward in adolescence. Families were originally recruited using a commercial mailing list targeting homes with an adolescent female between the ages of 8 and 14. For the current study, families from the larger study were invited to participate if they had an additional adolescent (male or female) in the household who was between the ages of 10 and 17. This second adolescent and their parent formed the dyad for the current study. Parents' (38 moms, 6 dads) mean age was 44.2 years (SD = 4.6), and adolescents' (20 girls, 24 boys) mean age was 12.9 years (SD = 2.1). Parents' racial and ethnic distribution was 86.4% Caucasian, 6.8% African American, 2.3% Asian and 4.5% 'Other'. Informed consent was obtained from the parent and informed assent from the adolescent. The research protocol was approved by the Stony Brook University Institutional Review Board.

Procedure

During the lab session parents and adolescents completed self-report questionnaires, and the parent completed a structured clinical interview to determine current and lifetime history of psychopathology. Parents and adolescents simultaneously completed the EEG guessing task in separate rooms.

Measures

Parenting style was measured using the Parenting Styles and Dimensions Questionnaire (PSDQ; Robinson *et al.*, 2001). The PSDQ is a 32-item self-report measure based on Baumrind's parenting styles typology (Baumrind, 1971), and includes three subscales: Authoritative (15 items; e.g. 'I emphasize the reasons for rules'), Authoritarian (12 items; e.g. 'I scold and criticize to make my child improve') and Permissive (5 items; e.g. 'I find it difficult to discipline my child') parenting. Each item is rated along a five-point Likert scale (1 = Never, 5 = Always), with higher scores indicating more frequent use of the parenting style.

Parental history of lifetime Axis I disorders was assessed using the Structured Clinical Interview for DSM-IV (SCID-IV; First *et al.*, 2002), conducted by doctoral and post-doctoral trainees and supervised by G.H.

Child self-reported anxiety symptoms were measured using the Multidimensional Anxiety Scale for Children (MASC; March *et al.*, 1997). The MASC consists of 39 items rated on a four-point scale (0 = 'never true about me' to 3 = 'often true about me'), and yields four subscales, with good documented psychometric properties (March *et al.*, 1997, 1999): Physical Symptoms (12 items, test-retest ICC = 0.92), Social Anxiety (9 items, test-retest ICC = 0.84), Harm Avoidance (9 items, test-retest ICC = 0.76) and Separation Anxiety/Panic (9 items, test-retest ICC = 0.85).

Guessing task

The guessing task was administered using Presentation software (Neurobehavioral Systems, Inc., Albany, CA) and was adapted from a similar version that has previously been used in single participants (Dunning and Hajcak, 2007; Foti and Hajcak, 2009, 2010; Foti *et al.*, 2011a; Bress *et al.*, 2012). In the traditional version of the guessing task, participants are shown an image of two doors, side-by-side, and are instructed to pick the winning door. For the dyadic version of the guessing task, participants picked the door themselves on half of the trials ('active trials') and on the other half of trials they observed a selection being made by someone who they were led to believe was the other member of the dyad ('observational trials'). Unbeknownst to the participant, on observational trials the door selection was computer-generated in order to standardize task performance. EEG was recorded simultaneously from the parent and adolescent in separate rooms. The sequence and timing of all stimuli were as follows: (i) the trial type was announced by presenting text that said either 'Your turn next. Click for next round' until the participant clicked or 'Their turn next...' for a randomized amount of time between 0 and 1000 ms, (ii) a fixation cross was presented for 500 ms, (iii) the graphic of two doors was presented until a selection was made after which a yellow border appeared around the selected door for 500 ms, (iv) a fixation cross was presented for 500 ms, (v) a feedback arrow was presented for 1000 ms, and (vi) a fixation cross was presented for 500 ms before the start of the next trial.

On active trials, participants were asked to guess the winning door by pressing the left or right mouse button. Following each choice, participants received feedback, such that a green up arrow indicated a win of $0.50 and a red down arrow indicated a loss of $0.25. Monetary gains were twice the value of monetary losses both because losses have been found to be subjectively weighted approximately twice as heavily as gains by subjects (Tversky and Kahneman, 1992), and the RewP is influenced by the subjective rather than the objective monetary value of losses and gains (Yeung and Sanfey, 2004; Sato *et al.*, 2005; Hajcak *et al.*, 2006).

On observational trials, participants were told to observe the other person selecting a door and receiving their feedback. All participants were informed that their outcomes were independent of the other person's performance. In order to preserve the illusion that the selections in observational trials were made by the other dyad-member, research staff entered the testing room during the break between the practice round and the task to let the participant know that the dyad partner was ready to continue when the participant was ready. To mimic variability in decision-making time, there was also a variable length of delay between 250 and 4000 ms before a 'selection' was made on observational trials.

The task consisted of 120 trials (30 wins, 30 losses, 30 observed wins and 30 observed losses). Order of the trial type (active or observational) and outcome type (gain or loss) was pseudorandomized. Trials were divided into two blocks of 60 trials each, and participants were given an untimed break between blocks. After the first block, text indicating the amount of money the participant had won thus far was presented. At the end of the task, the experimenter informed the participants how much money they had won in total. Parent-child dyads were paid the total amount of money they had won ($15) in cash at the end of the study.

EEG recoding and data processing

Continuous EEG was recorded using the ActiveTwo BioSemi system (BioSemi, Amsterdam, Netherlands) with a 34-channel custom elastic cap (i.e. 32-channel montage plus FCz and Iz), two electrodes on the right and left mastoids, and four facial electrodes. Eye movements and eye blinks were recorded using the four facial electrodes: two located ~1 cm outside the outer edge of each eye to measure horizontal eye movements; and two located ~1 cm above and below the right eye to measure vertical eye movements and blinks. The data were digitized at a sampling rate of 1024 Hz, using a low-pass fifth order sinc filter with 3 dB cutoff point at 104 Hz. Each active electrode was measured online with respect to a common mode sense (CMS) active electrode, located between PO3 and POz, producing a monopolar (non-differential) channel. CMS forms a feedback loop with a paired driven right leg electrode, located between POz and PO4, reducing the potential of the participants and increasing the common mode rejection rate.

Offline, the EEG data were analyzed in Brain Vision Analyzer (Brain Products GmbH, Gilching, Germany) referenced to the average of the left and right mastoids, and band-pass filtered from 0.1 to 30 Hz. Eye-blink and ocular corrections were conducted per (Gratton *et al.*, 1983). A semi-automatic procedure was employed to detect and reject artifacts. The automated criteria for exclusion of an electrode from a trial were a voltage step of more than 50.0 µV per ms between sample points, a voltage difference of 200.0 µV within 200 ms intervals, and a maximum voltage difference of < 0.50 µV within 100 ms intervals. Visual inspection of the data was then conducted to detect and reject any remaining artifacts. The EEG was segmented for each trial beginning 200 ms before each feedback onset and continuing for 1000 ms (i.e. for 800 ms following feedback). The average number of valid trials among parents for each experimental conditions was as follows: own gains = 30.00 ± 0.00; own loss = 29.98 ± 0.15; adolescent's gains = 30.00 ± 0.00; adolescent's loss = 29.95 ± 0.30. All 44 parents included had at least 29 segments for each trial type.

Stimulus-locked ERP waveforms were averaged separately for losses and gains, using the 200 ms before stimulus onset as
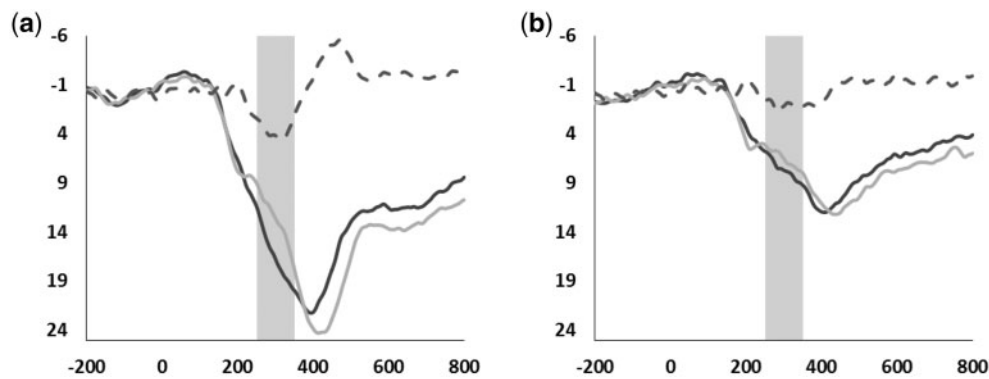
Fig. 1. ERP waveforms of the parental electrocortical response to their own outcome **(a)** and their child's outcome **(b)** measured at FCz.
Note: Horizontal axes represent time in ms; Vertical axes represent signal amplitude in μV, with negative values at the top of the chart. The time-windows (250–350 ms) used to calculate the RewP (a) and observational RewP (b) are highlighted in gray.

baseline. Visual inspection of the difference waveforms between gain and loss trials both for parent's own outcomes (ΔRewP) and adolescents' outcomes (observational ΔRewP) found that both difference waves were maximal at ~300 ms at FCz (Figure 1). Mean responses to gains and losses (i.e. RewP and FN) were thus scored separately as the average activity at FCz between 250 and 350 ms following the onset of outcome feedback. ΔRewP and observational ΔRewP were computed for active and observational trials, respectively, as subtraction-based difference scores between gain and loss trials (i.e. gains minus losses).[1]

Statistical analyses

We first conducted a 2 (outcome: gain or loss) × 2 (trial type: active or observational) repeated measures analysis of variance (rmANOVA) to statistically evaluate whether the expected patterns of ERP responses were elicited.

To assess relationships between parenting styles and parents' ERPs to observed child outcomes, we first calculated bivariate correlations between parents' observational ERPs and their self-reported parenting styles as measured by the PSDQ. We then employed hierarchical regression analysis to further test these relationships, adjusting for potential confounding variables thought to influence observational ERPs. Specifically, we adjusted for the sex of the parent, sex of the child, parental history of anxiety and mood disorders, and parents' responsiveness to their own monetary outcomes.

1 Though previous studies of the ERP response to observed monetary outcomes have reported only on th observational RewP and FN, we also include exploratory analyses using the parents' observational P3. While the RewP and FN are thought to uniquely distinguish between reward and loss (Foti *et al.*, 2011b; Yeung and Sanfey, 2004), the parietal ERP component dubbed the P3 has been suggested to uniquely index outcome magnitude, or the subjective salience of the outcome (Yeung and Sanfey, 2004). Thus, the parents' observational P3 may provide unique information about the salience of child outcomes to the parent. The P3 was scored as the mean activity between 350 and 550 ms at Pz. As anticipated, a 2 (outcome: gain or loss) × 2 (trial type: active or observational) rmANOVAof the P3 found a main effect of trial type ($F = 224.18$, $P < 0.001$), but not outcome ($F = 2.97$, $P > 0.05$), so a single observational P3 value for each participant, averaged across wins and losses, was used in data analysis. Analysis of the bivariate correlations between the observational P3 and parenting styles found that the observational P3 is negatively associated with the authoritarian parenting scores ($r = -.30$, $p < .05$) and not associated with authoritative or permissive parenting scores (P's > 0.05).

Table 1. Descriptive Statistics and correlation coefficients for the PSDQ scales and parent ERPs to observed adolescent outcomes

	1	2	3	4	5	6
1 Authoritative	–	−0.39**	0.03	0.27	0.01	−0.20
2 Authoritarian		–	0.45**	−0.32*	−0.34*	−0.09
3 Permissive			–	0.05	−0.08	−0.12
4 Parent Observational ΔRewP				–	0.37*	−0.41**
5 Parent Observational RewP					–	0.69**
6 Parent Observational FN						–
M	61.66	18.77	9.30	1.08	7.60	6.52
SD	6.38	4.83	3.44	4.10	5.20	5.29
Cronbach's α	0.79	0.80	0.79	–	–	–

Note: *$P < 0.05$; **$P < 0.01$; M, mean; RewP, Reward Positivity; FN, feedback negativity; ΔRewP, RewP minus FN; SD, standard deviation. Items 1–3 represent scores on the PSDQ scales.

We also conducted two sets of exploratory analyses to better understand how these parent measures may be associated with child functioning. First, we assessed whether parenting styles were also linked to the children's social neuroscience outcomes, as measured by the children's ERPs to parents' observed rewards and losses. Second, we sought to examine whether parents' observational ERPs (a) were associated with offspring psychopathology, specifically self-reported anxiety symptoms as measured by the MASC and (b) if also associated with parenting styles, whether these observational ERPs acted as a mediator between parenting styles and symptoms. Mediation analyses were conducted on 5000 bootstrap samples using the SPSS macro PROCESS (version 2.13.2; Hayes, 2013). This macro provides a regression-based bootstrap estimate of the indirect effect between the independent variable and dependent variable and 95% CI for the population value of the indirect effect. CIs that do not contain zero indicate a significant indirect effect. For mediational analyses, all variables were z-scored to produce standardized β weights.

Results

The rmANOVA found main effects of both outcome, $F(1,43) = 18.20$, $P < 0.001$, $\eta_p^2 = 0.30$, such that the RewP was more

Table 2. Hierarchical linear regressions with sex, parent's ERPs to own outcomes, parents' history of depressive and anxiety disorders, and PSDQ parenting style scales as the independent variables and parents' ERPs to observed outcomes as the dependent variables

	Observational ΔRewP			Observational RewP			Observational FN		
	F	Δ R²	β	F	Δ R²	β	F	Δ R²	β
Block 1	0.48	0.02		0.51	0.02		0.04	.00	
Adolescent Sex			−0.14			−0.13			−0.02
Parent Sex			0.10			0.13			0.04
Block 2	0.94	0.04		8.89**	0.38		8.58**	0.39	
Parent ERP to Own Outcomes			0.21			0.63**			0.63**
Block 3	0.60	0.01		6.08**	0.04		5.05**	0.01	
Parent Lifetime Depressive Disorders			−0.08			−0.15			−0.06
Parent Lifetime Anxiety Disorders			0.01			−0.17			−0.07
Block 4	1.35	0.16		4.64**	0.07		3.79**	0.07	
Authoritative			0.15			−0.12			−0.26
Authoritarian			−0.36†			−0.35*			−0.16†
Permissive			0.22			0.14			−0.03
Total R²		0.24			0.52			0.46	

Note: †$P < 0.10$; *$P < 0.05$; **$P < 0.01$; Sex was coded with females as the reference group. PSDQ, Parenting Styles and Dimensions Questionnaire.

Table 3. Descriptive statistics and correlation coefficients for the PSDQ scales and adolescent ERPs to observed parent outcomes
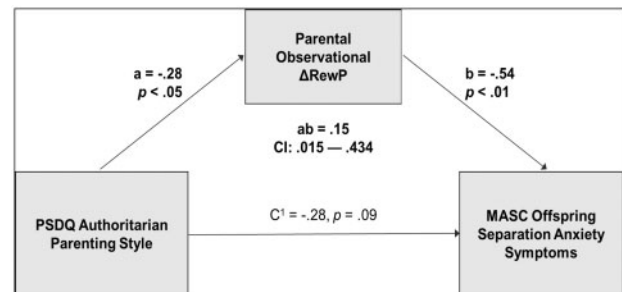
	1	2	3	4	5	6
1 Authoritative	−	−0.39**	0.03	0.18	0.14	−0.08
2 Authoritarian		−	0.45**	−0.02	0.02	0.04
3 Permissive			−	0.20	−0.07	−0.32*
4 Child Observational ΔRewP				−	0.63**	−0.57**
5 Child Observational RewP					−	0.27†
6 Child Observational FN						−
M	61.66	18.77	9.30	1.69	5.41	3.72
SD	6.38	4.83	3.44	5.07	5.37	6.31

Note: †$P < 0.10$; *$P < 0.05$; **$P < 0.01$; M, mean; RewP, reward positivity; FN, feedback negativity; ΔRewP, RewP minus FN; SD, standard deviation. Items 1−3 represent scores on the PSDQ scales.

Fig. 2. Relationship between Authoritarian Parenting and the Child Separation Anxiety Mediated through the Parents' Observational ΔRewP.
Note: All variables are z-scored. PSDQ, Parenting Styles and Dimensions Questionnaire; ΔRewP, Reward Positivity difference score, calculated by subtracting the response to losses (FN) from the response gains (RewP); MASC, Multidimensional Anxiety Scale for Children.

positive than the FN, and trial type, $F(1,43) = 108.29$, $P < 0.001$, $\eta_p^2 = 0.72$, such that the RewP and FN were more positive during active observational trials. There was also an interaction between outcome and trial type, $F(1,43) = 8.45$, $P < 0.01$, $\eta_p^2 = 0.16$, such that the difference score was smaller in the observational (i.e. observational ΔRewP) compared with the active (i.e. ΔRewP) condition (ERP waveforms shown in Figure 1).

Table 1 presents bivariate correlations among the PSDQ scales. Among the PSDQ subscales, higher authoritarian scores were associated with lower authoritative scores ($r = −0.39$; $P < 0.01$) and higher permissive scores ($r = 0.45$; $P < 0.01$). Table 1 also presents the bivariate correlations between the PSDQ scales and the parents' ERPs to the adolescents' monetary outcomes. Consistent with our hypotheses, greater authoritarian parenting scores were associated with smaller parental observational ΔRewP ($r = −0.45$; $P < 0.01$). When constituent ERPs (RewP and FN) were examined separately, higher authoritarian parenting scores were associated with a smaller parental observational RewP ($r = −0.34$; $P < 0.05$), but not observational FN ($P > 0.05$)[2].

2 Because of the small number of fathers in this sample, we conducted exploratory analyses with mothers only ($n = 38$) and found that all associations remain in the same direction but are reduced in significance such that authoritarian parenting is associated with the observational

Hierarchical regression analyses (Table 2) found that, adjusting for sex, parents' ERPs to own outcomes, parental history of depressive and anxiety disorders and the other parenting styles, authoritarian parenting significantly predicts a reduced observational RewP ($\beta = −0.35$, $t = −2.25$, $P < 0.05$), and predicts a reduced observational ΔRewP at the trend level ($\beta = −0.36$, $t = −1.87$, $P < 0.10$), but does not predict observational FN ($\beta = 0.16$, $t = −0.99$, $P = 0.33$).

Exploratory analyses examining the relationships between parenting styles and child observational ERPs (Table 3) found that permissive parenting was associated with blunted adolescent observational FN ($r = −0.32$, $P < 0.05$). Authoritative and authoritarian parenting scores were not associated with children's observational ERPs (P's > 0.05).

Exploratory analyses of relationships between parent observational ERPs and child anxiety indicated that greater MASC separation anxiety symptoms were associated with smaller parental observational ΔRewP ($r = −0.34$; $P < 0.05$), while greater MASC social anxiety symptoms were associated with a larger parental observational ΔRewP ($r = 0.35$; $P < 0.05$). Follow-up mediation analysis (Figure 2) found that the parents' observational

RewP at trend level (P 1), and is not significantly associated with observational ΔRewP.

ΔRewP mediated the relationship between authoritarian parenting and child separation anxiety symptoms [95% CI (0.015, 0.434)], but not the social anxiety symptoms (95% CI (−0.434, 0.002)]. The parents' observational ΔRewP was not associated with other MASC anxiety subscales or the MASC total anxiety scale.

Discussion

This study of 44 parent-child dyads found that self-reported authoritarian, or harsh, parenting is related to parents' diminished ERP responses to their adolescents' positive outcomes (i.e. the observational RewP and ΔRewP). This relationship between authoritarian parenting and parents' response to observed offspring rewards (the observational RewP) remained significant after adjusting for several factors thought to influence the neural response to observed reward, (i.e. sex, psychopathology and responsiveness to one's own rewards). After making the same adjustments, the association between authoritarian parenting and the difference score (ΔRewP) was reduced to trend level (P = 0.07). Contrary to our initial hypothesis, authoritative parenting was not significantly associated with a responsiveness to observed rewards. We also did not find significant associations between observational RewP and permissive parenting.

Exploratory analyses found a link between permissive parenting and children's blunted FN to observed parent outcomes. Perhaps surprisingly, neither authoritative nor authoritarian parenting was associated with changes in the children's observational ERPs. These findings are difficult to confidently interpret, though these alterations in empathic ERP responses appears consistent with previous literature indicating that permissive and not authoritarian parenting predicts greater offspring antisocial behaviors and that this relationship is mediated by impaired cognitive and affective empathy in the children (Schaffer et al., 2009). Finally, we found that blunted parental observational ΔRewP was associated with increased child separation anxiety symptoms. Furthermore, the observational ΔRewP mediated the relationship between authoritarian parenting and these symptoms. Collectively, these data suggest that the observational ΔRewP may add to our understanding of how parenting styles confer risk for psychopathology to the children. Nevertheless, because this small community sample of adolescents reported low anxiety scores, these associations with symptoms should be interpreted with caution.

One interpretation of the current findings is that authoritarian parenting is associated with reduced empathic processing of positive outcomes for the child. As previously noted, ERP responses to the monetary outcomes of others have been strongly implicated in empathic processing (Thoma and Bellebaum, 2012). Higher trait empathy and altruistic behaviors have both been linked to potentiation of observational ERPs (Fukushima and Hiraki, 2006; San Martín et al., 2016), while manipulations intended to reduce empathic feelings, such as making the task competitive, are associated with an attenuated observational ΔRewP (Marco-Pallarés et al., 2010). Similarly, authoritarian parenting has also been linked to a reduction of parents' self-reported empathic responses to their children (Coplan et al., 2002), particularly reduced empathic engagement in child successes. Behaviorally, authoritarian parening is characterized by a unidirectional communication style in which parents convey instructions to children and discourage the child from voicing their questions and concerns. Unsurprisingly, inattention to the child's thoughts and feelings has been linked to lower levels of parental perspective-taking (Gerris et al., 1997), a necessary

component of cognitive empathy (Davis et al., 1996). Furthermore, the specific attenuation of parents' empathic ERPs to child monetary wins, as compared with losses, suggests a mechanism for the reduced positive reinforcement characteristic of authoritarian parenting (Baumrind, 1971). If parents are specifically less responsive to offspring positive outcomes, they may be less likely to respond in a reinforcing way. Alternatively, authoritarian parents' blunted response to observed offspring rewards may reflect reduced need to attend to positive child outcomes when parenting is mainly focused on providing punishment.

Empathy for one's child represents a critical mechanism underlying adaptive parenting behaviors. Non-empathic parenting has been associated with increased risk for a range of mental health problems in the child (Psychogiou et al., 2008). Research into the neural correlates of parenting suggests that there is overlap in neural networks responsible for empathic responses and those that are thought to be uniquely activated in parents, dubbed the 'parental brain'. The parental brain is thought to play a role in initiating and sustaining a parent's motivation to prioritize the care of their offspring over self-interest (Swain, 2011; Lambert and Kinsley, 2012). This neural network includes several regions associated with perspective-taking and empathy (Swain, 2011), including mirror-neuron systems, the insula, and the inferior frontal gyrus. The hormone oxytocin, which is elevated in new mothers, has been implicated in the activation of the parental brain, and is thought to play a significant role in facilitating mother-infant bonding (Gordon et al., 2010). In a study of nulliparous women listening to infant crying sounds, that intranasal administration of oxytocin increased activity in the insula and the inferior frontal gyrus (Riem et al., 2011), two areas involved in generating empathic responses to others (Chakrabarti et al., 2006). Taken together, the literature suggests that empathy for one's offspring plays an important role in parenting, and that the brain undergoes changes in new parents, in order to increase the parent's feelings of empathy for their child.

The current data point to a possible neural mechanism underlying the harsh behaviors associated with authoritarian parenting (i.e. a dampened neural responsiveness to the successes of one's offspring, in particular). As noted earlier, authoritarian parenting can have significant negative clinical consequences for the offspring, including increased risk for anxiety and depressive disorders (Garber et al., 1997; Wolfradt et al., 2003). We find preliminary evidence that the deleterious effects of authoritarian parenting may be influenced by parents' responsiveness to observed offspring rewards, in that the association between authoritarian parenting and offspring separation anxiety symptoms was mediated by parents' observational RewP. Separation anxiety is often one of the earliest detectable forms of psychopathology and has been found to the genesis of other anxieties in later life (Milrod et al., 2014). Separation anxiety is particularly relevant when considering the impact of parenting, as a lack of trust in the parent is a central theme of separation anxiety. These findings tentatively suggest that parents' observational ERPs could provide a new way to assess dysfunctional parenting, and this new measure may in fact provide important information beyond what can be gleaned from self-reported parenting styles. Thus, the data in the current study may also begin to point to a potential target for treatment. Namely, by increasing parents' responsiveness to offspring successes, authoritarian parenting behaviors may be reduced, which may then help protect the offspring from future psychopathology. Future research is needed to better understand this

possible mechanism for authoritarian parenting and its potential as a target for treatment.

There are several limitations of the current study, and future research will be required to address them. First, at over 86% Caucasian, the ethnic makeup of the current sample had limited variability, yet research suggests that authoritarian parenting may not be detrimental across all cultures (c.f. Radziszewska *et al.*, 1996; Leung *et al.*, 1998). Indeed, in cultures where authoritarian parenting is normative, it has been associated with improved achievement outcomes (Leung *et al.*, 1998). These data suggest that authoritarian parenting may not always be indicative of reduced empathic responses to one's children. By extension, it is possible that authoritarian parenting will not always be associated with decreased neural responsiveness to offspring outcomes in cultures where authoritarian parenting is the norm.

Similarly, offspring attributions about the parent's behavior can make a significant difference in the consequences of parenting behavior. In one study, the relationship between parenting style and child outcomes was mediated by the attributions the child makes about their parent's intentions, irrespective of cultural context (Glasgow *et al.*, 1997). This suggests that, even if the observational ΔRewP does relate to parental empathy, if a child perceives his or her parents as empathic, then a blunted parental observational ΔRewP may not predict adverse consequences to the offspring. Future research should examine whether parents' blunted observational ΔRewP predicts long-term outcomes in offspring, and if so, whether those outcomes vary based on cultural context and on the child's attributions about their parents' behavior. Future research should also directly measure parental empathy to determine if empathy scores predict variability in the parents' observational ΔRewP to their offspring.

Finally, while we find preliminary evidence that parents' blunted ERP responses to observed offspring rewards may have negative consequences for the child's mental health, our small community sample was not ideally suited to assess these relationships. Specifically, the adolescents in the current sample were largely healthy, which meant there was inadequate symptom variance to assess the correlates of psychopathology.

This is the first study to examine the relationship between parenting style and parents' electrocortical responses to their adolescents' rewards and losses. The current findings point to a previously unexplored neural process that may index authoritarian parenting behaviors. Future research should seek to replicate these findings using a more ethnically diverse sample; assess offspring perception of their parent's behavior and state and trait measures of the parent's empathy; and use a sample with greater variance in child psychopathology to examine the potential mental health consequences for the offspring of a blunted parental observational RewP. Because parenting has such a significant impact on outcomes for the child, these ERP findings may be relevant for the development of childhood therapeutic interventions in two ways. First, the observational RewP may reflect a novel target for intervention. Specifically, the findings of this study suggest that authoritarian parenting may be linked to an insensitivity to their child's gains more than to their losses. Thus, parenting interventions may be most effective if they target the way parents respond to their child's 'successes'. Second, the observational RewP may be a useful measure of change after intervention (i.e. do parenting interventions meant to increase parental responsiveness also produce changes in parents' observational RewP to their children).

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