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Impact of early institutionalization on attention mechanisms underlying the inhibition of a planned action

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Abstract

Institutional rearing is associated with deficits in executive functions, such as inhibitory control, and may contribute to later externalizing behavior problems. In the current study, we explored the impact of institutional rearing on attention in the context of inhibiting a planned action. As part of the Bucharest Early Intervention Project (BEIP), children were randomized to either remain in the institutions in which they lived (Care as Usual Group) or be placed into foster family homes (Foster Care Group). We also recruited age and gender matched never-institutionalized (NIG) children from the Bucharest community. We examined differences in behavioral and Event Related Potentials (ERPs) during a go-no-go task when children were 12 years old. Results revealed that the ever-institutionalized group (CAUG and FCG combined) showed slower reaction times, worse performance accuracy, larger P2 activation, and smaller (less negative) N2 activation than the NIG group. Results of a moderation analysis revealed that children who spent more time in institutions and had small N2s showed more externalizing symptoms. These results have implications for the design of treatment approaches for previously institutionalized children with externalizing behavior problems.

Keywords

Early Institutionalization; Inhibiting a Planned Action; Externalizing Behavior; Event-Related Potentials; BEIP

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A large number of children reared in institutions exhibit signs of externalizing disorders (e.g., Humphreys, Gleason, Drury, Miron, Nelson, Fox, et al., 2015; Merz & McCall, 2010; Stevens, Sonuga-Barke, Kreppner, Beckett, Castle, Colvert, et al., 2008; Wiik, Loman, Van Ryzin, Armstrong, Essex, Pollak, et al., 2011; Zeanah, Egger, Smyke, Nelson, Fox, Marshall, et al, 2009). However, not all institutionally reared children go on to develop externalizing behavior problems (e.g., Humphreys, Gleason, Drury, Miron, Nelson, Fox, & Zeanah, 2015; Merz & McCall, 2010; Wiik, et al., 2011; also see review by Troller-Renfree, Zeanah, Nelson, & Fox, 2017). For example, Merz & McCall (2010) found that roughly between 20% and 35% of previously institutionalized children, primarily from Russia and Romania, compared with 10% of non-deprived adopted children in the US, showed externalizing behavior problems. Similarly, Wiik, et al. (2011) found that roughly 16% of previously institutionalized children adopted internationally, compared to 4% for non-adopted children, showed externalizing behavior problems. Additionally, the levels of externalizing behavior problems outlined by Wiik and colleagues (2011), as well as by Merz & McCall (2010) for previously institutionalized children is considerably higher than the 7.1% mean level of externalizing problems for non-previously institutionalized children (across 9 countries) found by Crijnen, Achenbach, and Verhulst (1997). Therefore, investigators have started to examine which factors might moderate the association between early institutional rearing and externalizing behavior (e.g., McDermott, Troller-Renfree, Vanderwert, Nelson, Zeanah, & Fox, 2013; Troller-Renfree, Nelson, Zeanah, & Fox, 2016). For example, Troller-Renfree, et al. (2016) found that brain activation associated with error processing moderated the association between amount of time spent in the institution and externalizing behaviors.

Additionally, several studies have shown that early institutional rearing contributes to deficits in executive functions (Bos, Fox, Zeanah, & Nelson, 2009; Bruce, Tarullo, Gunnar, 2009; Merz & McCall, 2011; Pollak, Nelson, Schlaak, Roeber, Wewerka, Wiik, et al., 2010; Tibu, Sheridan, McLaughlin, Nelson, Fox, & Zeanah, 2016), including inhibitory control (e.g., McDermott, Westerlund, Zeanah, Nelson, & Fox, 2012; Pollak, et al., 2010), i.e., the ability to inhibit a planned action (Schachar et al., 1995), and that deficits in inhibitory control are associated with externalizing behavior problems (Huijbregts, Warren, de Sonneville, & Swaab-Barneveld, 2008; Schachar, Mota, Logan, Tannock, & Klim, 1999; Schachar, Tannock, Marriott, & Logan, 1995; Tibu, Sheridan, McLaughlin, Nelson, Fox, & Zeanah, 2016). Thus, the current study examined if deficits in the ability to inhibit a planned action and perturbations in the neural correlates that contribute to inhibitory control might moderate the association between institutional rearing and externalizing symptoms.

To efficiently inhibit a planned action, several attention mechanisms need to be applied (as discussed in Aron, 2007; Cisek, 2007; Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004). To examine these attentional mechanisms, in the current study we measured three components of the event-related potential (ERP)—the P2, N2, and P3—in the context of a task that requires inhibition of a planned action (go-no-go task). ERPs were used to decompose the neural chronometry underlying the inhibition of a planned action because of their excellent temporal specificity (Kappenman & Luck, 2012; Hillyard & Anllo-Vento, 1998).

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Previous studies have associated P2 activation, a mediofrontal ERP found in adults roughly 200–300 ms after stimulus onset, with attentional orienting (Kanske, Plitschka, & Kotz, 2011; Maeno, Gjini, Iramina, Eto, & Ueno, 2004; Van Voorhis & Hillyard, 1977). Furthermore, Loman and colleagues found that in the context of a go-no-go task previously institutionalized children had larger P2s for no-go trials compared to go trials but that this effect was not evident for non-institutionalized children (Loman, Johnson, Westerlund, Pollak, Nelson, & Gunnar, 2014). Thus, we predicted that P2 activation would be enhanced in previously institutionalized children and moderate the association between institutional rearing and externalizing symptoms; specifically, that institutionalized children with large P2s would show the most externalizing symptoms.

Studies have associated N2 activation—a mediofrontal ERP found in adults roughly 250–350 ms after stimulus onset—with various aspects of cognitive control, including response monitoring or response conflict (Bartholow, Pearson, Dickter, Sher, Fabiani, Gratton, 2005; Dimoska, Johnstone, & Barry, 2006; Donkers & van Boxtel, 2004; Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003; van Veen & Carter, 2002). Loman and colleagues (2014) also examined the impact of institutionalization on N2 amplitudes and found that N2s were smaller (less negative) for institutionalized children compared to non-institutionalized children. Additionally, Troller-Renfree, et al., (2016), using the same sample, found that another mediofrontal ERP also associated with response processing (the ERN) moderated the association between amount of time-spent-in-the-institution and externalizing behavior problems. Therefore, we predicted that institutionally reared children with smaller N2s would show the most externalizing symptoms but that this would not be the case for institutionally reared children with large N2s, i.e., that the N2 would moderate the association between time-spent-in-the-institution and externalizing symptoms.

Lastly, the P3 —an ERP component that peaks in adults roughly at 300 ms after stimulus onset—has been associated with context updating in working memory (Donchin, 1981; for a review see Polich, 2012). McDermott et al. (2012) found deficient P3 activation for previously institutionalized and foster care children compared to never institutionalized children in the context of a go-no-go task. Thus, we predicted that children who were institutionally reared would exhibit smaller P3 amplitudes and that children with small P3s would show the most externalizing symptoms.

The goals of the current study are to determine: 1) if removal from an institution and subsequent placement in foster care early in life impacts neural activation underlying one's ability to inhibit planned actions, at age 12 years, and 2) if patterns of neural activation (P2, N2, and P3) underlying the ability to inhibit a planned action moderates the association between amount of time-in-institution and externalizing symptoms. These questions were explored in the context of the Bucharest Early Intervention Project (BEIP), the first randomized control trial of a foster care intervention for institutionalized children (for details see Zeanah, Nelson, Fox, Smyke, Marshall, Parker, & Koga, 2003).

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Method

Participants

Participants were part of the Bucharest Early Intervention Project (BEIP; Zeanah, et al., 2003), a randomized controlled trial comparing the effects of foster care as an alternative to institutional care for young children abandoned at birth and placed in institutions. For a detailed breakdown of the history, design, and implementation of this study, please see Zeanah, et al., 2003. This study assessed 136 children between the ages of 6 and 31 months who were institutionalized in Bucharest, Romania, and who at that time had spent at least half of their lives living in an institution. After initial assessment of all children, half of the institutionalized sample (n = 68; 33 boys and 35 girls) was randomly assigned to continued institutional care (care as usual, CAU) and the other half of the sample (n= 68, 34 boys and 34 girls) was assigned to foster care (FC; see Zeanah et al., 2003, for a full description of the sample). Both groups (CAUG and FCG) were followed systematically through 12 (mean = 12.63, SD = .55) years of age. Additionally, a separate never institutionalized group (NIG) of age- and gender-matched children (n = 52, 23 boys and 29 girls; mean age = 12.68, SD = .39) from the Bucharest area were recruited as a comparison group. The current study presents ERP and clinical symptom data collected at 12 years of age and includes 144 participants (CAUG: male 26, female 21; FCG: male 26, female 23; NI: male 22, female 26). Participants were excluded from this study for a number of reasons, including that the child did not participate in the 12-year visit (11 CAUG, 12 FCG), go-no-go data was missing (8 CAUG, 6 FCG, 4 NIG), and because ERPs were comprised of too few artifact free trials (2 CAUG, 1 FCG). Missing data was compared to analyzed data for differences in gender, $\chi^2(1, N = 188) = 3.05$, $p = .08$, age, $t(156) = -.18$, $p = .86$, ethnicity, $\chi^2(3, N = 188) = 4.73$, $p = .19$, group status, $\chi^2(2, N = 188) = 10.06$, $p = .007$, and severity of externalizing symptoms, $t(157) = -.58$, $p = .56$. For the significant group status analysis, fewer NIG children had missing data for the 12-year visit than CAUG and FCG children.

Measures

Diagnostic Interview Schedule for Children, 4th Edition; DSM-IV (DISC; Shaffer et al., 2000). The DISC is a structured psychiatric interview assessment tool that is both reliable and valid for children 6 years and older. The DISC probes current symptom levels, duration or persistence, age of onset, and functional impairment. For the NIG and FCG groups, the parent report was obtained from the mother if available, otherwise fathers provided the report. For the CAUG children, an institutional caregiver who worked with the child regularly and knew them well reported on the child's behavior. For more information on how the DISC was administered within the BEIP study, please see Humphreys, et al. (2015). For the current study, only the Attention-Deficit/Hyperactivity Disorder (ADHD), Oppositional Defiant Disorder (ODD), and Conduct Disorder (CD) modules were used. The Mean internal consistency values for our study was .77.

MacArthur Health and Behavior Questionnaire (HBQ; Luby, Heffelfinger, Measelle, Ablow, Essex, Dierker, et al., 2002). The HBQ parent report is a reliable and valid measure of the physical and mental health of young children. This measure yields dimensional ratings of current functioning in the domains of 1) emotional and behavioral symptomatology, 2)

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physical health, 3) social adaption, and 4) school adaptation, to comprise 18 subscales covering a number of behavior problems, including ADHD and externalizing symptoms. The Mean internal consistency values for our study was .88. For the current study, we used the same reporter for the CAUG, FCG, and NIG children as described above for the DISC.

Go-no-go Task (McDermott et al., 2012). The current task was a modified version of the traditional letter go-no-go task (Conners, 2000) and was presented on a 17-in computer monitor using E-Prime software (Psychological Software Tools, Pittsburgh, PA; Schneider, Eschman, & Zuccolotto, 2002). The timing and appearance of the traditional go-no-go task was altered slightly to make it appropriate for an ERP task (see Figure 1). Stimuli were shown on a black screen and consisted of single letters presented in white (170-point size upper case, Times New Roman). The current task consisted of 70% go trials and 30% no-go trials. This ratio of go to no-go trials ensures a response prepotency (i.e., requiring enhanced response control for the no-go trials). This ratio of trials occurred pseudo randomly (each participant got the same trial order) within 2 blocks of 140 trials each. Throughout the task, no-go trials were always separated by at least one go trial. Prior to these 140 trials, each block consisted of a string of 20 go trials (not included in percentages above) to train participants to have a response prepotency, thereby making it more difficult to inhibit responding when a no-go stimulus was presented. The total number of trials presented was 320 (not including the 10-trial practice block). Each trial consisted first of a fixation image (100 ms) followed by a stimulus image (500 ms) and a blank black screen (500 ms). All no-go trials presented the letter “X”. Go trials consisted of all other letters except the letter “K”.

EEG data collection and analyses

EEG was recorded using a 64-channel Geodesic Sensor Net and sampled at 250 Hz, using EGI software (Net Station; Electrical Geodesic, Inc., Eugene, OR [data were also processed using Net Station]). Once the impedance values for all EEG channels were reduced to below 50 kΩ, data acquisition began. During recording, all channels were referenced to Cz and after acquisition, data were re-referenced using an average reference.

Data were filtered using a FIR bandpass filter with a low pass frequency of 30 Hz and a high pass frequency of .3 Hz. To best capture eye blink artifacts, the threshold was set to 140 μV (peak-to-peak) and all trials in which this threshold was violated were excluded from analyses. Furthermore, signal activation change (peak-to-peak) exceeding 125 μV across the entire segment and fast transits exceeding a difference (peak-to-peak) of 100 μV across 2 samples (8 ms) were marked as bad and interpolated. After automatic artifacting was completed, participant data were visually inspected to ensure artifact criteria were applied appropriately.

Procedure

After consent and assent were attained, children were seated in a chair 96 cm from the computer screen. The electrode sensor net was applied and the go-no-go task was administered. Children played a 10-trial long practice block to ensure proficiency of the task. Participants moved on to the actual task if they reached 60% accuracy. All participants reached this criterion and no participants had to repeat the practice block.

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Data analyses—Waveforms for correct go and no-go trials were segmented into epochs from 200 ms before to 600 ms after stimulus onset and baseline corrected for the 200 ms preceding stimulus onset. Inspection of the grand-averaged ERP waveform indicated that mediofrontal P2 activation was maximal between 210 and 310 ms, mediofrontal N2 activation was maximal between 315 and 415 ms, and parietal P3 activation was maximal between 300 and 550 ms after stimulus onset; thus, peak activation was exported for these time windows. To eliminate trials characterized by attentional lapses or chronic non-responding, no-go trials that did not have a correct go trial preceding and following them were removed from analyses. Due to this strict criterion, the mean number of trials comprising correct no-go ERPs was 44.47 (SD = 13.90; range = 11–75). Mean number of trials comprising correct go ERPs was 134.33 (SD = 30.16; range = 28–182). Traditionally, N2 activation has been analyzed as no-go activation minus go activation (e.g., Falkenstein, Hoormann, & Hohnsbein, 1999; Mathalon, Whitfield, & Ford, 2003). However, there is recent evidence that conducting difference scores on ERPs brings about bias (Meyer, Lerner, De Los Reyes, Laird, & Hajcak, 2017). Therefore, we removed go activation from no-go activation using linear regression and analyzed the standardized residuals.

Visualization of the correct go and no-go stimulus-locked waveforms revealed clear N1, P2, and N2 components for mediofrontal electrodes and a clear P3 at parietal electrodes (see Figure 2). Consistent with previous literature (e.g., Falkenstein, et al., 1999; Gajewski, Stoerig, & Falkenstein, 2008; Nieuwenhuis, Yeung, & Cohen, 2004), P2 and N2 activation was exported for electrodes Cz and FCz, and the average activation across these electrodes was analyzed to limit the number of analyses performed, while the P3 was analyzed at electrode Pz.

Preliminary Analyses

To determine if potential gender differences might affect analyses, a priori t-tests were run (see Table 1). Gender was controlled for (added as a covariate) in all analyses that showed significant gender differences in Table 1.

Because there is considerable debate about what is the best ERP data extraction procedure, i.e., mean or maximum/minimum values, all analyses were conducted on both types of data. Patterns of results were the same across both types of data but maximum/minimum yielded slightly stronger effects, so these were reported.

To prevent potential Type I errors, we limited the number of analyses conducted on externalizing variables by making three composite scales measuring ADHD, ODD, and CD symptoms. The ADHD symptom composite consisted of HBQ inattention and impulsivity variables, and DISC inattention, hyperactivity, and impulsivity variables. All variables were standardized and then averaged together. The same procedure was applied to comprise the ODD and CD symptom composite scales. The ODD composite scale was comprised of HBQ oppositional defiant, DISC ODD mood, and DISC ODD defiant scales. Lastly, the CD composite scale was comprised of HBQ conduct and DISC violent CD. See below for a correlation table between these symptom composite scales and both ERP and behavioral measures (see Table 2).

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Each subsection of the results section is organized starting with our intent-to-treat analyses (Little & Yau, 1996; t-test examining differences between FCG and CAUG groups) to assess results of the randomized controlled trail (RCT), followed by group difference analyses (t-test examining differences between ever institutionalized and never institutionalized children), and finally, moderation analyses examining if ERP amplitudes moderated the association between time-in-institution and externalizing behavior symptoms. Time-in-institution was calculated as percent time that each child had lived in an institution at age 12. Reduced t-test degrees of freedom shown below are due to violation of the homogeneity of variance assumption. Additionally, to determine if ERP activation moderated the association between time-in-institution and externalizing behavior symptoms, we conducted a number of hierarchical linear regression analyses. Percent-time-in-institution (independent variable) and ERP activation (moderator) were entered in step one. The interaction term between time-in-institution and ERP activation was entered in step two. The dependent variables consisted of three composite symptom variables: conduct disorder (CD), oppositional defiant disorder (ODD), and attention deficit hyperactivity disorder (ADHD), which were entered into separate analyses.

Ethical considerations

Parents or guardians provided consent at each time point and children assented to participate in this study at 12 years of age. All children assented to each procedure.

This study received IRB approval from Boston Children's Hospital (protocol number 10-04-0185; with the University of Maryland relying on this protocol) and Tulane University (protocol number 196018). Ethical dimensions of the study have been discussed by us (Nelson, Fox, & Zeanah, 2014; Zeanah, Fox, & Nelson, 2012; Zeanah, Koga, Simion, Stanescu, Tabacaru, Fox, & Nelson, 2006[a,b]) and by others (Miller, 2009; Millum & Emmanuel, 2007; Rid, 2012).

Results

Behavioral Data

Intent-to-treat.—We conducted independent samples t-tests to explore reaction time and performance accuracy differences between our CAUG and FCG groups. Results revealed significant differences only for go reaction times, $t(85) = 2.46$, $p = .02$, CAUG Mean = 381.18, FCG Mean = 356.46, indicating that the FC group had faster reaction times than the CAU group. There were no intervention effects for no-go reaction times or go and no-go performance accuracy: $t(94) = 1.78$, $p = .08$, CAUG M = 338.19, FCG M = 315.27; $t(94) = -.49$, $p = .62$, CAUG M = .94, FCG M = .94; $t(94) = .67$, $p = .50$, CAUG M = .70, FCG M = .68.

Group differences.—To ascertain the differential behavioral performance for ever institutionalized (EI) children, i.e., children in the CAU and FC groups combined, compared with NIG children, we conducted independent samples t-tests for go and no-go reaction times, as well as go and no-go performance accuracy. Results revealed worse go performance accuracy, $t(135) = -5.26$, $p < .001$, EIG M = .94, NIG M = .98, and slower

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erroneous reactions times (no-go trials), $t(139) = 2.26$, $p = .03$, EIG M = 326.49, NIG M = 307.62, for the EI group compared to the NI group. The reaction time results suggest that errors for the EIG children occur later than for the NIG children in the cognitive sequence required to inhibit a planned action. Non-significant results were found for no-go performance accuracy, $t(119) = -.37$, $p = .72$, EIG M = .69, NIG M = .70, and go reaction times, $t(122) = 1.64$, $p = .10$, EIG M = 368.56, NIG M = 356.41.

P2 Results

Intent-to-treat.—We conducted independent samples t-tests to explore differences in go and no-go P2 activation between our CAU and FC groups. Results revealed non-significant effects for go, $t(94) = .77$, $p = .44$, CAUG M = 2.30, FCG M = 1.79, and no-go, $t(94) = .02$, $p = .98$, CAUG M = 4.33, FCG M = 4.31, trials.

Group differences.—To explore group differences in P2 activation between EIG and NIG children, we conducted separate t-tests for go and no-go trials. Results revealed larger no-go P2s for the EI group than the NI group, $t(142) = 2.78$, $p = .006$, EIG M = 4.32, NIG M = 2.52. For go trials, results were not significant, $t(142) = 1.89$, $p = .06$, EIG M = 2.04, NIG M = .99.

Moderational analyses.—Next, to determine if no-go P2 amplitude moderated the association between time-in-institution and externalizing behavior symptoms, a number of moderation analyses were conducted (as outlined above). Results revealed a main effect of time-in-institution on both CD, $\beta = .29$, $t(92) = 2.85$, $p = .005$, and ODD, $\beta = .27$, $t(92) = 2.56$, $p = .01$, but not ADHD, $\beta = .09$, $t(92) = .87$, $p = .39$. Additionally, no main effect of P2 was found for any of the externalizing measures: CD, $\beta = .002$, $t(92) = .02$, $p = .98$; ODD, $\beta = -.04$, $t(92) = -.41$, $p = .68$; ADHD, $\beta = -.12$, $t(92) = -1.12$, $p = .24$. Lastly, no significant interaction was found between time-in-institution and P2 on CD, $\beta = .15$, $t(92) = 1.44$, $p = .15$; ODD, $\beta = -.05$, $t(92) = -.48$, $p = .64$, or ADHD, $\beta = .01$, $t(92) = .10$, $p = .92$.

N2 Results

Intent-to-treat.—We conducted an independent samples t-test to explore if no-go activation (with go activation regressed out) differed between our CAU and FC groups. This t-test did not yield a significant difference, $t(94) = .73$, $p = .47$, CAUG M = .17, FCG M = .03.

Group differences.—To explore group differences in N2 activation (no-go with go regressed out), we conducted a t-test comparing EIG children with NIG children. Results revealed that the EI group had less negative N2s than the NI group, $t(142) = 2.01$, $p = .05$, EIG M = .10, NIG M = −.21.

Moderational analyses.—Next, to determine if N2 activation (no-go with go regressed out) moderated the association between time-in-institution and externalizing behavior symptoms, we conducted a number of hierarchical linear regression analyses. Results revealed a main effect of time-in-institution on both CD, $\beta = .26$, $t(92) = 2.61$, $p = .01$, and ODD, $\beta = .26$, $t(92) = 2.44$, $p = .02$, but not ADHD, $\beta = .06$, $t(92) = .56$, $p = .57$.

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Additionally, no main effect of N2 was found for any of the externalizing measures: CD = β = .10, $t(92) = 1.03$, $p = .31$; ODD = β = .07, $t(92) = 68$, $p = .50$; ADHD = β = .06, $t(92) = .57$, $p = .57$. Lastly, a significant interaction was found between time-in-institution and N2 on CD, β = .20, $t(92) = 1.98$, $p = .05$ (see Figure 3). However, no such interaction was found for the ODD, β = −.05, $t(92) = -.44$, $p = .66$, or ADHD, β = .08, $t(92) = .76$, $p = .45$, composite variables.

To decompose the interaction between percent-time-in-institution and N2 activation on CD, simple slopes were tested by re-calculating N2s into new variables representing high and low N2 activation, and running additional regression analyses using the re-calculated scores, as suggested by Aiken, et al. (1991). Follow-up analyses showed that when N2 activation was less negative, time-in-institution was related to CD symptoms, β = .51, t(92) = 3.69, p<.001. However, when N2 activation was more negative, time-in-institution was unrelated to CD symptoms, β = .02, t(92) = .10, p=.92. Thus, children who stayed in the institution for a large amount of time and had small (less negative) N2s, displayed higher levels of CD symptoms.

P3 Results

Intent-to-treat.—We conducted two independent samples t-tests to explore differences in go and no-go P3 activation between our CAU and FC groups. Results revealed no significant P3 differences: go, $t(94) = .13$, $p = .89$, CAUG M = 9.76, FCG M = 9.64; no-go, $t(94) = .64$, $p = .52$, CAUG M = 12.96, FCG M = 12.23.

Group differences.—To explore group differences in P3 activation between EIG and NIG children, we conducted separate t-test on no-go and go activation. No significant Group effects were found for either go, $t(142) = -.36$, $p = .72$, EIG M = 9.70, NIG M = 9.98, or no-go, $t(142) = -.71$, $p = .48$, EIG M = 12.59, NIG M = 13.26, trials. Because we found no group differences in P3 activation, we did not conduct moderation analyses on P3s.

Discussion

We examined whether children with a history of psychosocial deprivation showed differential amounts of neural activation underlying the ability to inhibit a planned action, and if amounts of neural activation moderated the association between institutional rearing and symptoms of externalizing behavior. To inhibit a planned action, a number of attention mechanisms need to be deployed (Aron, 2007; Cisek, 2007; Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004), the extent of which can be measured using ERPs.

Previous studies suggest that P2 activation might be a neural marker underlying attentional orienting (Kanske, Plitschka, & Kotz, 2011; Maeno, Gjini, Iramina, Eto, & Ueno, 2004; Van Voorhis & Hillyard, 1977). Loman, et al., (2013) found that previously institutionalized children had larger P2s for no-go trials than go trials but that never institutionalized children did not show this differentiation. Consistent with the works of Loman, et al. (2013), our group analyses found that the ever-institutionalized group (EIG; CAUG and FCG combined) recruited more no-go P2 activation, had worse performance accuracy, and slower erroneous reaction times than the NI group. Together, these results suggest that the CAU and FC

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groups may be orienting their attention towards important cues inefficiently compared to the NI group, and that their inefficient attention orienting may in part contribute to their worse behavioral performance.

Once attention has been oriented toward an event that might require action, then it becomes necessary to determine if and what action needs to be initiated, potentially leading to a conflict between response strategies. The N2 has been associated with response conflict or response monitoring (Bartholow, et al., 2005; Dimoska, et al., 2006; Donkers & van Boxtel, 2004; Nieuwenhuis, et al., 2003; van Veen & Carter, 2002). Consistent with previous literature (Kishiyama, et al., 2008; Loman, et al., 2013; McDermott, et al., 2012; McFarlane, et al., 2005), we found that early severe psychosocial deprivation, such as that generally found in institutions, impacts patterns of N2 activation. We found that the EI group had smaller (less negative) N2s than the NI group. If we examine these results in the context of our P2 results, it may be that the EI group performs poorly (low accuracy and slow reaction times) in part because they have difficulty orienting their attention to an important response cue (the no-go X) and then subsequently have limited conflict processing (response conflict/conflict monitoring) resources making it difficult to initiate the correct response in a timely manner.

We also examined if institutional rearing altered P3 activation, an ERP component that has been associated with context updating in working memory (e.g., Donchin, 1981; for a review see Polich, 2012). Previous studies have shown variable results, with some showing clear effects of institutional rearing on P3s (e.g., Evren-Guler, et al., 2012), while others, like our study, did not (e.g., Loman, et al., 2013). These conflicting results might be due to the different tasks used. Studies that showed P3 effects, compared to those that did not, used tasks with a memory component, e.g. old vs. new picture recognition (Evren-Guler, et al., 2012; Loman et al., 2013).

We also were interested to see if ERP measures reflecting commonly-studied attention processes moderated the well-established association between institutional rearing and externalizing behavior. Indeed, the N2 moderated this association but not the P2 or P3, suggesting that it is the combination of extended placement in the institution and insufficient N2 activation, reflecting inadequate conflict processing, that leads to more conduct-disorder-like symptoms. Previous studies have linked N2s with activation in the anterior cingulate cortex (ACC), ventral prefrontal cortex (vPFC), and dorsolateral prefrontal cortex (DLPFC; Bocquillon, Bourriez, Palmero-soler, Molaee-Ardekani, Derambure, & Dujardin, 2014; Lamm, Walker, Degnan, Henderson, Pine, McDermott, & Fox, 2014; Lamm, White, McDermott, & Fox, 2012; Lavric, Pizzagalli, & Forstmeier, 2004; Pandey, Tang, Roopesh, Stimus, Rangaswamy, & Porjesz, 2012). Furthermore, for children who experienced severe early adversity, such as institutionalization, compared with typically-developing children, studies have found reduced ACC and prefrontal activation (Cohen, Grieve, Hoth, Paul, Sweet, Tate, et al., 2006; Escobar, Huepe, Decety, Sedeno, Messow, Baez, et al., 2014; Kim, Kim, Jin, Im, & Lee, 2018), reduced prefrontal cortical thickness (Dannlowski, Stuhrmann, Beutelman, Zwanzger, Lenzen, Grotegerd, et al., 2012; McLaughlin, Sheridan, Winter, Fox, & Nelson, 2014), and abnormal white matter connectivity (Bick, Zhu, Stamoulis, Fox, Zeanah, & Nelson, 2015; Eluvathingal, Chugani, Behen, Juhasz, Muzik, Maqbook, et al.,

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2006; Hanson, Adluru, Chung, Alexander, Davidson, & Pollak, 2013; Sheridan, Fox, Zeanah, McLaughlin, & Nelson, 2012) and that duration of adversity may impact the severity of neural deficit (Bick, et al., 2015; Hodel, Hunt, Cowell, van den Heuvel, Gunnar, & Thomas, 2015). Additionally, deficits in these prefrontal brain regions have been associated with externalizing behavior problems (e.g., Best, Williams, & Coccaro, 2002; Lamm, Granic, Zelazo, & Lewis, 2011; Lotze, Veit, Anders, & Birbaumer, 2007; New, Buchsbaum, Hazlett, Goodman, Koenigsberg, Lo, et al., 2004; Rubia, Smith, Halari, Matsukura, Mohammad, Taylor, et al., 2009). Thus, it is likely that our moderating effect reflects the combined effects of early adversity, i.e., extended placement in the institution, and individual differences in these neural deficits. These results speak to the need to limit the duration of institutional rearing and suggest that treatment of externalizing behavior problems might incorporate training in conflict processing.

Limitations

This study had a number of limitations. First, we used only caregiver reports to establish externalizing behavior problems. However, given the impairment level of our sample, self-reporting is likely not meaningful. Second, as with most ERP studies of children, our study analyzed ERP components based on relatively low numbers of trials (mean no-go trial count was 44). We found no group differences in no-go trial count, CAUG vs. FCG: $t(94) = 1.16$, $p = .25$, CAUG M = 45.04, FCG M = 41.63; EIG vs. NIG: $t(142) = -1.43$, $p = .15$, EIG M = 43.30, NIG M = 46.81; thus, trial count should not have biased our results.

Conclusions

The current study explores the impact of adverse rearing environments on several attention mechanisms underlying the ability to inhibit a planned action. Results indicate that early institutional rearing impacts both P2 and N2 activation, reflecting attention orienting and conflict processing, and that deficits in N2 activation moderate the association between institutional rearing and antisocial behavior. Future research should explore if these attention deficits can be ameliorated with treatment.

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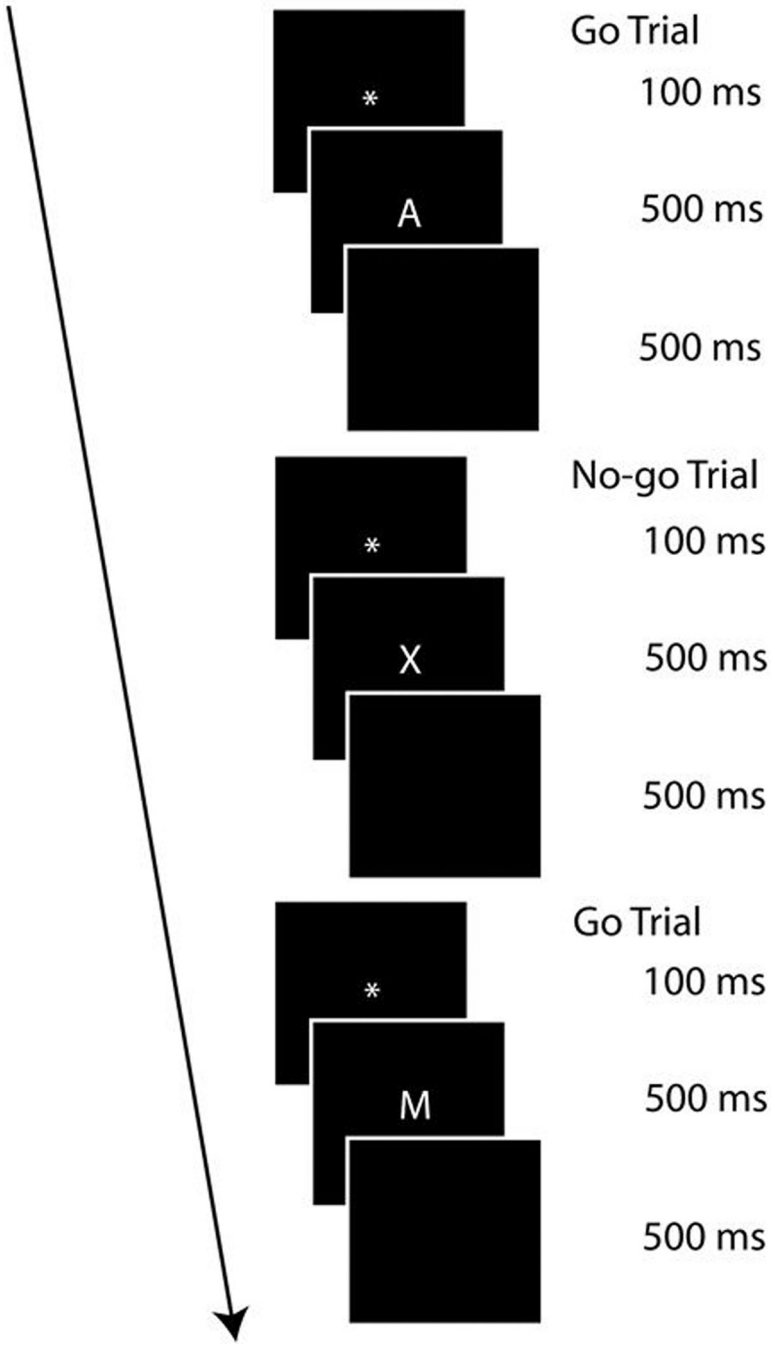

Figure 1.
Go-no-go task diagram showing three trials

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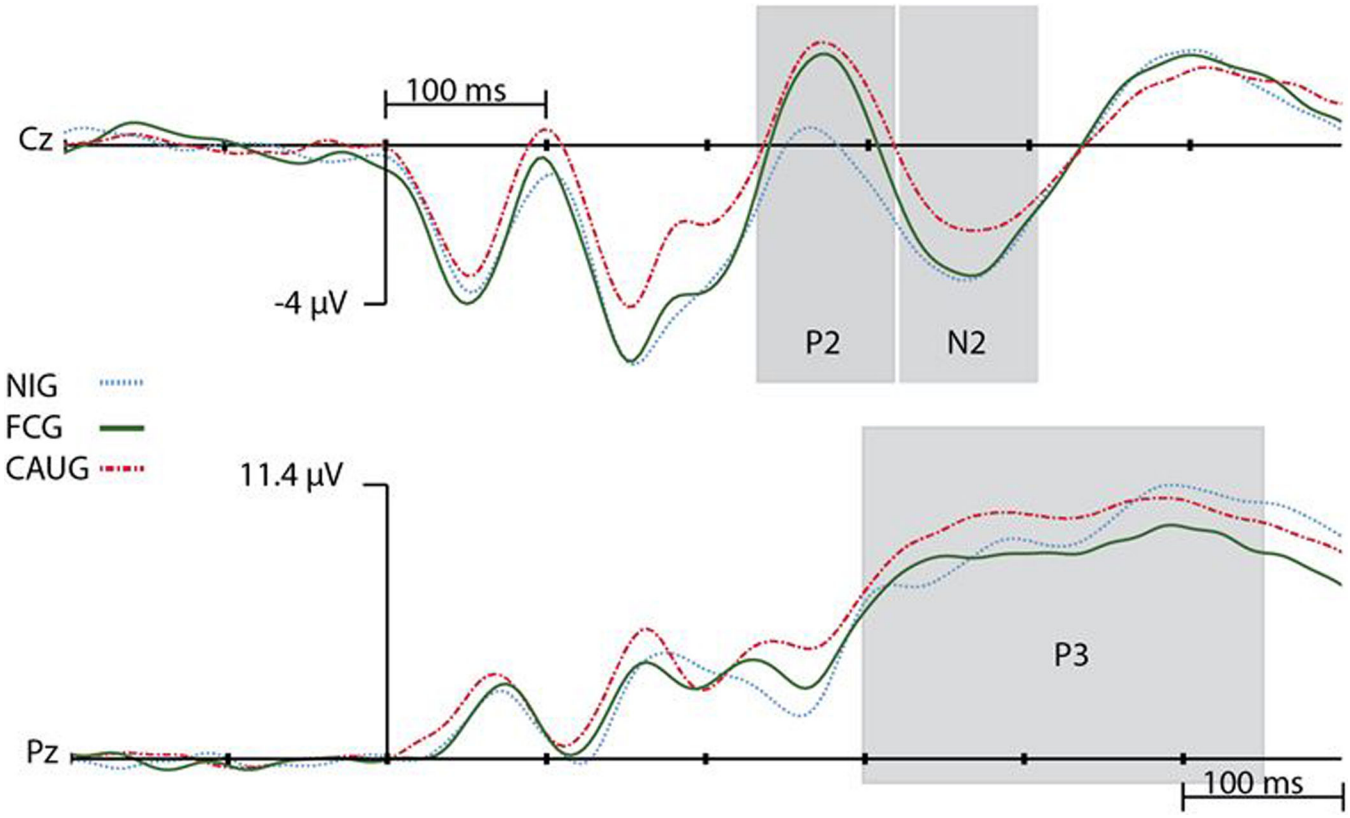

Figure 2.
Correct no-go activation waveforms (μV). Positive activation is up.

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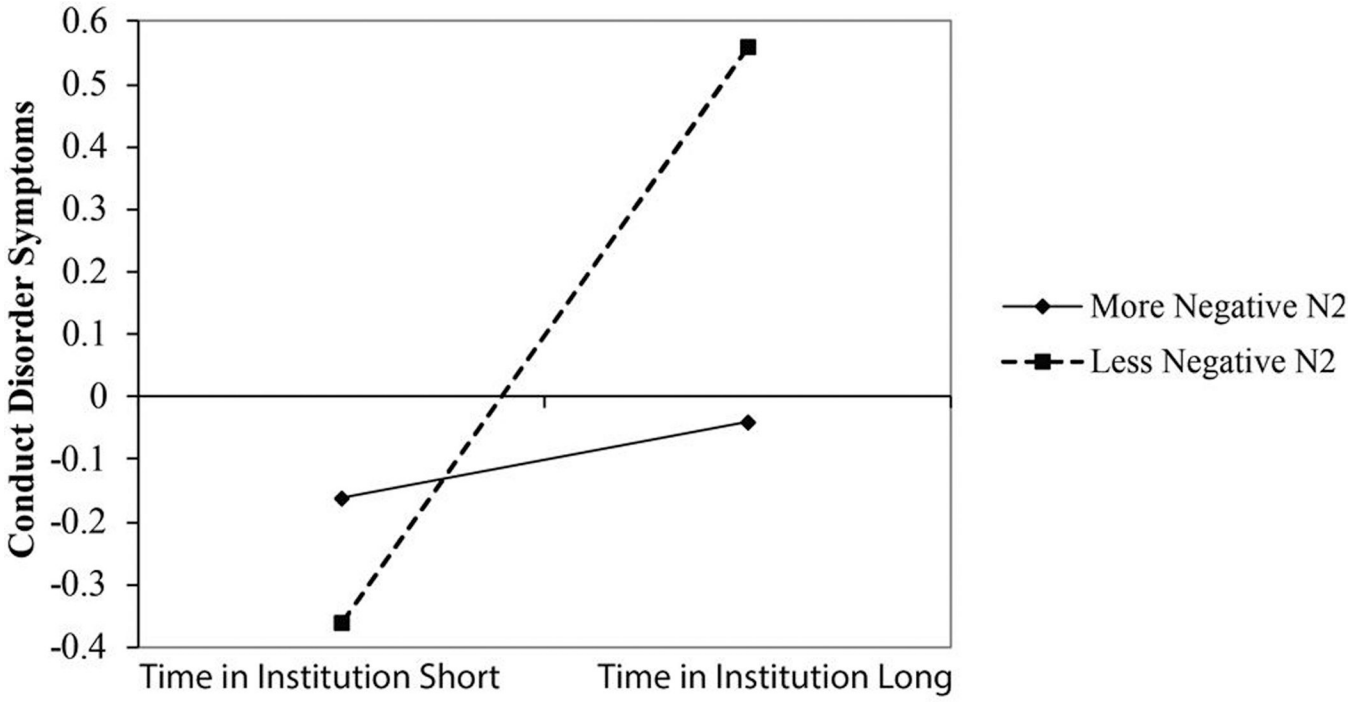

Figure 3.

Moderation plot showing that the association between time in the institution and conduct-disorder-like symptoms is moderated by N2 (no-go with go regressed out) activation. Activation is average of Cz and FCz.

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Table 1.

Gender differences with means and standard deviations

Variable Name	Gender Differences	Male	Female
Go P2 amplitudes	$t(142) = -.79$, $p = .43$	1.89 (1.89)	1.47(1.47)
No-go P2 amplitudes	$t(142) = .64$, $p = .52$	3.53(4.03)	3.93(3.42)
No-go (with go regressed out) N2 amplitudes	$t(142) = -.80$, $p = .43$	.05(1.00)	−.07(.74)
Go P3 amplitudes	$t(142) = -1.21$, $p = .23$	10.22(4.66)	9.34(4.11)
No-go P3 amplitudes	$t(142) = -2.34$, $p = .02$ *	13.81(5.66)	11.76(4.82)
Go reaction times	$t(142) = .34$, $p = .39$	361.23(46.96)	367.99(46.15)
No-go reaction times	$t(142) = -.55$, $p = .58$	322.74(64.66)	317.51(47.03)
Go performance accuracy	$t(142) = 1.04$, $p = .30$	.95(.06)	.96(.05)
No-go performance accuracy	$t(142) = 2.15$, $p = .03$ *	.67(.13)	.72(.13)
CD Symptoms	$t(142) = -1.14$, $p = .26$	.07(.87)	−.08(.76)
ODD Symptoms	$t(142) = -1.83$, $p = .07$	.13(.88)	−.13(.82)
ADHD Symptoms	$t(142) = -3.42$, $p = .001$ *L	.23(.93)	−.24(.72)

L Equal variances not assumed (significant Levene's test)

* Significant Gender differences

CD = Conduct Disorder; ODD = Oppositional Defiant Disorder;

ADHD = Attention Deficit Hyperactivity Disorder

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Table 2.

Pearson correlations between all clinical, ERP, and behavioral measures

	1	2	3	4	5	6	7	8	9	10	11	12
1. CD	--	0.61**	.59**	.03	.02	.006	−.14	.14	.09	.08	.005	.01
2. ODD		--	.74**	.10	.12	−.24**	−.22*	.13	.03	.06	.03	.07
3. ADHD			--	.009	.06	−.24**	−.24**	.09	−.006	−.03	−.02	.000
4. Go RT				--	.70**	−.23**	.44**	.08	.03	.008	−.10	−.08
5. No-go RT					--	−.38**	.22**	−.008	−.05	−.08	−.02	−.04
6. Go Acc.						--	.28**	−.10	−.007	−.01	.13	.15
7. No-go Acc							--	.04	.13	.15	.04	−.03
8. N2								--	.15	.39**	.10	.16
9. Go P2									--	−83**	−.07	−.09
10. No-go P2										--	−.03	−.03
11. Go P3											--	.69**
12. No-go P3												--

*Significant < or = .05;

**Significant < or = .05

Acc = performance accuracy; RT = reaction times; N2 = no-go N2 with go removed

CD = conduct disorder; ODD = oppositional defiant disorder; ADHD = attention deficit hyperactivity disorder