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J Abnorm Child Psychol. Author manuscript; available in PMC 2014 August 01.

Published in final edited form as:
J Abnorm Child Psychol. 2013 August ; 41(6): 879–890. doi:10.1007/s10802-013-9737-9.

Inhibitory Control and Working Memory in Post-Institutionalized Children

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Abstract

Inhibitory control and working memory were examined in post-institutionalized (PI) children adopted into United States families from Russian institutions. The PI sample originated from institutions that were less severely depriving than those represented in previous studies and approximated the level of psychosocial deprivation, which is characterized by adequate physical resources but a lack of consistent and responsive caregiving. PI children (N=75; 29 male) ranged in age from 8–17 years (M=12.97; SD=3.03) and were grouped according to whether they were adopted after 14 months or before 9 months. A non-adopted comparison group (N=133; 65 male) ranged in age from 8–17 years (M=12.26; SD=2.75). PI children adopted after 14 months of age displayed poorer performance on the stop-signal and spatial span tasks relative to PI children adopted before 9 months of age after controlling for age at assessment. The two PI groups did not differ in their performance on a spatial self-ordered search task. Older-adopted PI children also showed poorer spatial span task performance compared to non-adopted children, but younger-adopted PI children did not. Task performance was significantly associated with parent-rated hyperactive-impulsive behavior in everyday contexts. These findings suggest that exposure to prolonged early institutional deprivation may be linked with inhibitory control and working memory difficulties years after adoption.

Keywords

early deprivation; post-institutionalized children; inhibitory control; working memory

In the past 20 years, more than 300,000 children were adopted internationally into the United States (US Department of State, 2009), most of them from institutional settings. Early institutionalization is linked with increased rates of persistent attention, cognitive, and academic difficulties (MacLean, 2003; Stevens et al., 2008). Recent findings suggest that post-institutionalized (PI) children may have underlying difficulties with executive processes such as inhibiting automatic responses to goal-irrelevant stimuli and storing and processing information in working memory (Pollak et al., 2010). Studies examining institutional quality or level of deprivation have centered on PI children adopted from severely or "globally" depriving institutions characterized by inadequate physical resources, such as nutrition and medical care, as well as profound psychosocial deprivation (Rutter et

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al., 2007). However, early exposure to less severely depriving institutions, such as psychosocially depriving institutions characterized by adequate physical resources but a lack of consistent and responsive caregiving, may also be associated with executive function difficulties (Pears et al., 2010). The current study examined inhibitory control and working memory in PI children adopted from less severely depriving institutions than those represented in previous studies. Associations between these executive processes and parent reports of children's attention difficulties in everyday contexts were also explored.

Attention, Cognitive, and Academic Difficulties in Post-Institutionalized Children

PI children provide an opportunity to study the developmental effects of a circumscribed period of early deprivation as well as the potential for recovery following placement into usually stable and well-educated middle-class families (Hellerstedt et al., 2008). Following adoption, marked improvements in physical, social, and cognitive development are generally observed (van IJzendoorn, Juffer, & Poelhuis, 2005). However, studies consistently find that PI children have significantly greater attention problems, lower IQ scores, greater likelihood of receiving learning support services, and lower reading and math achievement scores than children reared in their biological homes and children adopted at young ages from non-institutional settings (Fox, Almas, Degnan, Nelson, & Zeanah, 2011; Loman et al., 2009; Rutter et al., 2007). In particular, problems with inattention and hyperactivity-impulsivity have been found in multiple studies of PI children and shown to persist years after adoption (Gunnar et al., 2007; Kreppner, O'Connor, & Rutter, 2001; MacLean, 2003; Rutter, Kreppner, & O'Connor, 2001; Stevens et al., 2008). While PI children also have elevated rates of attention-deficit/hyperactivity disorder (ADHD; Miller, Chan, Tirella, & Perrin, 2009), some evidence suggests that they differ in presentation from children with ADHD who do not have histories of early deprivation (Sonuga-Barke & Rubia, 2008).

Inhibitory Control and Working Memory in Post-Institutionalized Children

While the majority of the PI literature has relied on parent and teacher reports and broad-based measures of general cognitive functioning, recent interest has turned toward examining specific neurocognitive processes that may link early deprivation and poor developmental outcomes (Marshall & Kenney, 2009). In animal models, there is evidence that early deprivation may produce deficits in executive functioning (Sanchez, Ladd, & Plotsky, 2001), a set of cognitive skills that facilitate goal-directed behavior (Best & Miller, 2010). Executive functioning is associated with activation in prefrontal cortex (Chambers, Garavan, & Bellgrove, 2009) and represents a unified latent construct that entails the coordination of several interrelated, but distinct, component skills including inhibitory control and working memory (Garon, Bryson, & Smith, 2008; Miyake et al., 2000). Development of these specific skills is closely associated with the ability to regulate attention (Rueda, Posner, & Rothbart, 2005). Improvements in executive function skills often support emerging competencies in the social, behavioral, and academic domains (Hughes, 2011).

A few studies have investigated inhibitory control and working memory among 6- to 11-year-old PI children (Bruce, Tarullo, & Gunnar, 2009). PI children showed poorer performance on "simple" inhibitory control tasks assessing the ability to withhold a primary or dominant response (e.g., go/no-go, stop-signal tasks; Eigsti, Weitzman, Schuh, De Marchena, & Casey, 2011; McDermott, Westerlund, Zeanah, Nelson, & Fox, 2011) as well as on more complex inhibitory or interference control tasks assessing suppression of a competing secondary response (e.g., Stroop, knock and tap, flanker tasks; Colvert et al., 2008; Pollak et al., 2010) compared to children reared in their biological families and to

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children adopted at young ages from non-institutional settings. Given that complex inhibitory control tasks require the integration of multiple cognitive processes, including working memory, simple tasks may more purely reflect inhibitory control (Best & Miller, 2010).

Working memory can be divided based on whether it refers to verbal or visual-spatial information, and these systems can be further subdivided into short-term storage/ maintenance and updating/processing components (Alloway, Gathercole, & Pickering, 2006). Studies of PI children have examined verbal and spatial updating/processing (Bauer, Hanson, Pierson, Davidson, & Pollak, 2009; Beckett, Castle, Rutter, & Sonuga-Barke, 2010). In the Cambridge Neuropsychological Test Automated Battery (CANTAB; Cambridge Cognition, UK) spatial working memory task, children search spatial locations to find tokens while remembering not to return to any locations where tokens were previously found. PI children displayed greater spatial working memory deficits than children adopted at young ages from non-institutional settings such as foster care (Pollak et al., 2010). In the Bucharest Early Intervention Project (BEIP), children exposed to institutional deprivation had greater spatial working memory difficulties than children reared in their biological families (Bos, Fox, Zeanah, & Nelson, 2009).

Some studies have addressed whether executive function difficulties in PI children may be related to poor birth circumstances. Pollak et al. (2010) found differences between PI and non-institutional adopted groups on working memory despite these groups not differing significantly in birth weight. In contrast, the BEIP found that birth weight contributed significantly to performance on the spatial working memory task (Bos, Fox, Zeanah, & Nelson, 2009).

Another important question centers on the extent to which performance on tasks in a lab setting reflects day-to-day functioning. In the English and Romanian Adoptees (ERA) study, among 11-year-old PI children, Stroop task performance was associated with parent- and teacher-reported inattention and hyperactivity (Colvert et al., 2008; Sonuga-Barke & Rubia, 2008). More research is needed that examines associations between direct assessments of inhibitory control and working memory and observations of PI children's attention functioning in their everyday lives.

Age at Adoption

The likelihood of attention and cognitive problems increases with age at adoption or time in an institution. At 11 years of age, the ERA study of children adopted from severely or globally depriving Romanian institutions found a threshold effect or step function at 6 months. Specifically, children adopted before 6 months did not differ significantly from never-institutionalized children adopted within the United Kingdom (UK) at young ages; children adopted after 6 months were at increased risk, but within this group, there was no association between age at adoption and attention or cognitive outcomes (Rutter et al., 2007). Studies of children adopted from less severely depriving institutions have suggested a step-function at older ages of adoption, such as after 18–24 months (Gunnar et al., 2007; Merz & McCall, 2010; Nelson et al., 2007).

Few studies have examined age at adoption effects with regard to executive functioning. Results from the ERA study indicated a step function at 6 months for Stroop task errors (Beckett et al., 2010; Colvert et al., 2008). Other studies of executive function have limited their PI samples to children placed in family settings after 9–12 months (Bos, Fox, Zeanah, & Nelson, 2009; Pollak et al., 2010). Taken together, findings across studies indicate that PI children adopted before 6–9 months do not differ from typically-developing children, whereas PI children adopted after 12–14 months have greater executive function problems.

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Thus, younger-adopted children represent a useful comparison group for older-adopted children.

Early Psychosocial Deprivation

Under typical family rearing conditions, inhibitory control and working memory emerge in the first year of life and develop rapidly over the course of early childhood (Best & Miller, 2010; Garon, Bryson, & Smith, 2008; Hughes, 2011; Rueda, Posner, & Rothbart, 2005). Caregivers are theorized to initially act as external regulators of the infant’s functioning, gradually facilitating the child’s increasing capacity to self-regulate. Studies of general development have found that caregiver responsiveness and scaffolding support executive function development during early childhood (Bernier, Carlson, & Whipple, 2010; Kochanska, Murray, & Harlan, 2000; Landry, Smith, & Swank, 2006). Children exposed to early adverse care (e.g., maltreatment, multiple foster placements, caregiver disruptions) have an increased risk of executive functioning difficulties (Lewis, Dozier, Ackerman, & Sepulveda, 2007; Pears, Fisher, Bruce, Kim, & Yoerger, 2010).

Based on these studies, early exposure to the psychosocial deficiencies of institutions may play an important role in PI children’s executive function difficulties. Executive processes have been studied among children adopted from globally depriving institutions that are profoundly lacking in both physical and psychosocial resources (Colvert et al., 2008) and PI samples composed of children adopted from several different world regions (e.g., Asia, Latin America, Eastern Europe) likely to have varied institutional deprivation histories (Eigsti et al., 2011; Pollak et al., 2010). However, less is known about these skills in children adopted from psychosocially depriving institutions that provided adequate physical resources but primarily failed to provide a consistent set of responsive caregivers (Gunnar, 2001).

Several Russian institutions were found to provide adequate material resources but expose children to frequent changes in caregivers and a lack of sensitive, responsive caregiving. Specifically, in these institutions, nine or more different caregivers often worked with a group of 12 to 14 children in a given week, and children were periodically “graduated” to new groups with different caregivers. By 19+ months of age children had potentially experienced 60 to 100 caregivers (St. Petersburg-USA Orphanage Research Team, 2005). Caregivers rarely initiated social interactions, responded to infants’ social bids, responded promptly to emotional distress, or provided warmth and affection (Muhamedrahimov, 1999; see also Tirella et al., 2008). School-aged children adopted primarily from these psychosocially depriving institutions at older ages had higher levels of parent-reported executive function difficulties than those adopted at younger ages and the normative sample (Merz & McCall, 2011). This PI sample also had lower levels of parent-reported behavior and executive function difficulties than PI children adopted from globally depriving institutions after accounting for age at adoption (Merz & McCall, 2010; Merz, McCall, & Groza, in press).

Current Study

The purpose of the current study was to examine inhibitory control and working memory in 8- to 17-year-old PI children. Tasks assessed the inhibition of a primary response (stop-signal task) as well as short-term storage/maintenance plus updating/processing of spatial items (spatial span and self-ordered search tasks). PI children adopted after 14 months of age were expected to show poorer performance on these tasks relative to PI children adopted before 9 months of age. These age at adoption groups were chosen to be consistent with prior literature while also accommodating within-group sample size. As a supplemental

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analysis of spatial span task performance, both PI groups were compared to children reared in their biological families; the older-adopted PI group was expected to have greater difficulties than children reared in their biological families but the younger-adopted PI group was not. We also examined whether poor birth circumstances were associated with inhibitory control and working memory difficulties among the PI children. In addition, it was predicted that older-adopted PI children would have higher levels of parent-rated attention problems than younger-adopted PI children and the rating scale standardization sample and that task performance would be associated with parent-rated attention problems.

This study was designed to increase our understanding of the neurocognitive mechanisms underlying early deprivation effects by focusing on executive functioning measures that allow inferences into underlying neural circuitry. Although psychosocial deficiencies of institutions are thought to impact children's executive function development, previous studies have demonstrated executive function deficits in PI children with severe or varied deprivation histories. The current study addressed whether less severely depriving institutional backgrounds are also associated with executive function problems. This study also compared older- and younger-adopted PI groups whereas previous studies limited their PI samples to children adopted at older ages. In addition, the current research addressed whether PI children's task performance aligned with their attention regulation in everyday life.

Method

Post-Institutionalized (PI) Participants

Recruitment and response rate—PI participants were recruited through an adoption agency specializing in adoption from high quality Russian institutions. Most of the participants had also participated at one or more time points in our main study of children adopted through this agency which examines child behavior and development through parent-report questionnaires (Merz & McCall, 2010). Eligible parents received a letter of invitation and a follow-up phone call.

The participation rate was about 54%. Primary reasons for declining participation included lack of interest and time demands. According to a selective responding check conducted on our main study sample, parents of children with more difficulties were no more likely to respond to a single questionnaire than parents of children with fewer adjustment difficulties (Hawk et al., in press). In addition, multivariate analysis of covariance (MANCOVA) was conducted to examine whether participants in the current study (n=65) and in the main study (n=143) differed on Behavior Rating Inventory of Executive Functioning (Gioia, Isquith, Guy, & Kenworthy, 2000) Inhibit and Working Memory scale T scores after covarying age at assessment and age at adoption. There were no significant differences between current study and main study participants on parent-rated inhibitory control or working memory, Wilks' λ = .99, F(2,203)=.55, *ns*.

Sample characteristics—Participants were 75 8- to 17-year-old children adopted from institutions that were carefully screened for relatively high quality by the adoption agency and primarily located in St. Petersburg, Russia (68%); 54% came from the psychosocially depriving institutions described in the introduction (St. Petersburg-USA Orphanage Research Team, 2005). Children adopted from these psychosocially depriving institutions (54% of the sample) did not differ significantly from the remainder of the sample in inhibitory control or working memory, Wilks' λ = .97, F(3, 67) = .60, *ns*. The larger main study sample, from which the current sample was drawn, has been found to have lower behavior and executive function problem rates than children adopted from severely depriving institutions (Merz & McCall, 2010; Merz, McCall, & Groza, in press).

There were 41 children adopted ≤ 9 months (range: 4–9 months) and 34 children adopted ≥ 14 months (range: 14–48 months). Although some children had spent pre-adoption time in the care of their birth families, all children in the sample had spent ½ or more of their time prior to adoption in institutions. Children were excluded from analyses if they had marked functional deficits (e.g., an autism spectrum disorder diagnosis in combination with cognitive impairment) or a fetal alcohol spectrum disorder (FASD) diagnosis (n=5). As shown in Table 1, there were no differences between the groups in terms of the number of boys versus girls and child's age at assessment. The adoptive families of the two groups were similar; most of the adoptive parents were married/partnered and had a high education and household income. In total, 19 children were taking stimulant medications; eight children were tested when they were not taking the medication. The percentage of children taking stimulant medication at the time of testing did not differ between groups (see Table 1).

Procedure—PI children and their parents were visited at their homes in Pittsburgh, Philadelphia, or Washington D.C. one time for approximately two hours by a researcher. After parent and child consent was obtained, the tasks were presented to the child. Computerized tasks were presented on a touch screen attached to a laptop that faced the researcher; depending on the task, the child used either the touch screen or a button box to input responses. The researcher administered the CANTAB motor screening task first followed by the inhibitory control and working memory tasks and two IQ subtests in a sequence that varied across children. While the child participated in these tasks, the parent completed a questionnaire that asked about family characteristics and the child's background, early development, medical history, and service use and included the Conners' Parent Rating Scale – Revised (CPRS; Conners, 2000). Parents and children were compensated $30 each for their participation.

Non-Adopted (NA) Children

NA participants were typically-developing children reared in their birth families who completed the spatial span task as part of a separate study. This group had no reported history of neurological or psychiatric disorders in themselves or their first-degree relative. Participants were 133 8- to 17-year-old children with equal numbers of boys and girls (Asato, Nawarawong, Hermann, Crumrine, & Luna, 2011). The PI and NA children did not differ significantly in terms of age at assessment, $F(2,203) = 1.22$, *ns*, or gender, $\chi^2(2,N=206) = 3.54$, *ns*.

Measures

Inhibitory control and working memory—The CANTAB (Cambridge Cognition, UK) stop-signal, spatial span, and spatial working memory tasks were administered. The CANTAB has been shown to possess acceptable to high levels of concurrent validity and test-retest reliability and to be differentially sensitive to disturbances in various brain systems (De Luca et al., 2003; Luciana & Nelson, 2002; Strauss, Sherman, & Spreen, 2006).

Stop-signal task: In this task (Logan, Schachar, & Tannock, 1997), equally probable right- and left-pointing arrows were presented on a computer screen, and the child was instructed to respond by pressing the corresponding keys as quickly as possible with his/her dominant hand. On 25% of the trials, an auditory stop-signal presented shortly after the arrow indicated not to respond. Each trial consisted of a 500 ms fixation followed by an arrow appearing for one second and an inter-trial interval of 700 ms. The stop-signal consisted of a 1000 Hz tone 100 ms in duration. Five blocks of 64 trials were administered following one practice block of 16 trials. This task utilizes a tracking procedure, in which the delay between the presentation of the arrow and the onset of the stop-signal changes after every

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trial with a stop-signal. The task starts with a 250 ms delay. Following a successful stop, the delay is lengthened by 50 ms resulting in the next stop trial being harder. Following a failed stop, the delay is shortened by 50 ms resulting in the next stop trial being easier. This procedure converges on the stop-signal delay at which the child is able to inhibit on 50% of the trials. Stop-signal reaction time (SSRT), the primary outcome measure, reflects inhibitory control speed or the time required to stop a response that is already in the process of being executed. It is computed as the difference between the mean stop-signal delay and the mean RT on trials without a stop-signal (Logan et al., 1997). Longer SSRT indicates poorer inhibitory control.

Checks on data integrity were conducted. The probability of inhibition was very close to 50% in each group suggesting that SSRT was estimated accurately. In addition, the PI groups did not differ significantly in terms of percentage of accurate inhibition or stop-signal delay. However, for two children, percentage of inhibition was < 13% potentially yielding questionable estimates of SSRT (Nigg, 1999). Main analyses were re-run omitting sub-blocks in which percentage of inhibition was < 13%, with no change in results. The stop-signal task requires canceling an already-initiated or ongoing motor response (Crosbie, Perusse, Barr, & Schachar, 2008). Stop-signal task data were not obtained for two PI children due to computer error.

Spatial span task: A set of 10 white boxes is displayed on the touch screen and a specified number of boxes change color for 3 seconds, one at a time. The participant is then signaled by a tone to reproduce the sequence by touching the same boxes in the same order on the touch screen. If the participant touches the appropriate boxes in the correct order, he/she passes to the next level of difficulty. If the participant fails to give the correct response, two more attempts are allowed at each level. The task is discontinued after three failures at a given level. The task starts with a two-box sequence and it is possible to advance to a nine-box sequence. Prior to the start of test trials, the child is given two practice trials to ensure his/her understanding of the task. The score on this task is the number of items that can be remembered in the correct order.

Spatial working memory task: The test begins with a number of colored squares ("boxes") displayed on a touch screen. The child is asked to find one blue token in each of these boxes and use the tokens to fill up an empty column on the right side of the screen. The child is instructed that after a token has been found in a box, that box will not contain any tokens in the future. Therefore, the child has to remember in which boxes tokens were found previously so as to not return to those boxes. There are three fixed levels of the task (4, 6, and 8 boxes) with four trials at each level. The outcome measure is the number of total errors (touching boxes already found to be empty and revisiting boxes already found to contain a token).

Cognitive functioning—The Vocabulary and Matrix Reasoning subtests of the Wechsler Intelligence Scales for Children – Fourth Edition (WISC-IV; Wechsler, 2003) were used to estimate full-scale IQ. The scaled scores (M=10, SD=3) for these subtests were summed, and full-scale IQ scores (M=100, SD=15) were estimated based on Sattler and Dumont (2004). This short form of the WISC-IV had high reliability (.92) and validity (.87) in the standardization sample (Sattler & Dumont, 2004).

Inattention and hyperactivity-impulsivity—The long version of the CPRS (Conners, 2000) has 80 items. Parents are asked to rate their child's behavior in the last month on a 4-point scale from 0 (not true at all) to 3 (very much true). The *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (*DSM-IV) Inattentive* and *Hyperactive-Impulsive* scales were used in this study. The *Inattentive* scale (9 items) assesses poor

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attention to detail, careless mistakes on schoolwork, difficulty sustaining attention, failure to follow through on instructions, difficulty organizing tasks and activities, avoidance of tasks that require sustained mental effort, and distractibility. The *Hyperactive-Impulsive* scale (9 items) assesses fidgetiness, difficulty remaining seated, excessive motor activity or restlessness, responding out of turn, and interrupting. CPRS norms are based on a nationally representative standardization sample ($N = 2{,}482$). Separate norms are given for boys and girls, in three-year intervals, for ages 3 through 17. The CPRS yields T scores (higher scores indicate greater problems) which have a population mean of 50 ($SD = 10$); T scores 1.5 SD above the normative mean are considered to be in the clinical range. Adequate reliability and validity coefficients have been reported for the CPRS. Cronbach's alpha ranged from .73–.94 for CPRS scales in the standardization sample. Test-retest reliability coefficients over a span of 6–8 weeks ranged from .67–.85 for a sample of 50 children with a mean age of 11 years (Conners, 2000). The parents of one PI child did not complete the CPRS.

Pre-adoption history—Age at adoption was defined as the age at which the child came into the parents' full-time care. Parent-reported time in an institution was strongly correlated with age at adoption, $r = .94$, $p < .001$, reflecting that most children were placed in institutions in the first few months of life. Age at adoption was used in analyses rather than time in an institution because it was more frequently and likely more accurately reported.

Parents provided their child's birth weight and whether their child's birth was premature. Birth weight was reported for 70% of the sample, and prematurity data were given for 79% of the sample. Low birth weight (LBW) was defined as weighing less than 5.5 pounds at birth; 35% (18/51) of the children with birth weight data were coded as LBW. As expected, prematurity was significantly associated with LBW, $\chi^2(1, N=51)=31.63$, $p<.001$.

Post-adoption history—Parents indicated their highest level of education completed, family income before taxes in $25,000 increments up to $200,001+, and marital status. Education responses were dichotomized into those families in which at least one parent had a 4-year college degree or more vs. those with less education. Income responses were dichotomized into families with a household income of $100,000 or more vs. those with lower income. Parent marital status responses were dichotomized as married/partnered or not married/partnered.

Statistical Analyses

After inspecting all dependent variables for deviations from the required assumptions, SSRT, Inattentive scale, and Hyperactive-Impulsive scale scores were log-transformed to address slight departures from normality. As described below, analyses of the Hyperactive-Impulsive scale scores accounted for violation of the assumption of homogeneity of variances across PI groups. MANCOVA was used to examine PI group differences in inhibitory control and working memory with one between-groups factor (adopted ≤ 9 or ≥ 14 months) and one covariate (age at assessment). Wilks' lambda was used as the overall test of significance and if the overall omnibus F was significant ($p < .05$), the subsequent univariate analyses were interpreted. ANCOVA was conducted to examine differences among the PI children adopted ≤ 9 months, PI children adopted ≥ 14 months, and NA children in spatial span length after covarying age at assessment. PI group differences in parent ratings of attention were analyzed using t tests, and the test of group differences in Hyperactive-Impulsive scores adjusted for violation of the assumption of equal variances. The effect size Cohen's d was reported. The conventions for small, medium, and large effects are .20, .50, and .80, respectively (Cohen, 1992).

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Pearson correlations and *t* tests were used to examine potential birth effects. Bivariate correlations between task scores and parent ratings were investigated using Pearson correlations. Associations with Hyperactive-Impulsive scale scores were also analyzed using Spearman's rank correlation coefficient. Multiple linear regression was used to examine whether these associations were accounted for by age at adoption or age at assessment.

Results

As expected, inhibitory control and working memory task performance improved with age at assessment, r = .26–.57, p<.05, but parent-rated attention problems were not associated with age at assessment, r = .03–.21, *ns*. There were no gender differences in task performance, $t(73)$=.58–1.16, *ns,* or parent-rated attention problems, $t(72)$ = .12–.33, *ns*. There were no group differences on the CANTAB motor screening task error score, $F(1,73)$=1.34, *ns*, or latency score, $F(1,73)$=1.28, *ns,* suggesting that basic differences in motor skills may not confound any other differences found between the groups. The PI group adopted ≥ 14 months had a significantly lower IQ than the PI group adopted ≤ 9 months (see Table 1), although both means were in the average range, and IQ was significantly associated with performance on the spatial span task, r=.27, p<.05, but not the spatial working memory task, r=−.19, p=.10, or the stop-signal task, r=−.10, *ns*. In the larger executive function literature, researchers have noted overlap in what is measured by executive function and IQ tasks suggesting that covarying IQ may obscure deprivation effects on executive processes (Dennis, Francis, Cirino, Schachar, Barnes, & Fletcher, 2009). Based on these preliminary analyses, age at assessment was included as a covariate in main analyses involving task performance.

Analyses were conducted to examine the validity of the age at adoption groups. There were no significant correlations between age at adoption and inhibitory control or working memory task performance (or parent-rated inattention or hyperactivity-impulsivity) within either the PI group adopted ≤ 9 months (r = .02–.18, *ns*) or the PI group adopted ≥ 14 months (r = .15–.29, *ns*). Children taking stimulant medication on the day of the assessment (n=11), children taking stimulant medication but *not* on the day of the assessment (n=8), and children not taking stimulant medication (n=56) did not differ significantly in inhibitory control, $F(2,71)$=1.55, *ns,* or working memory, $F(2,71)$=.22–.76, *ns*, although results were limited by small sample size within the groups taking medication.

PI Group Differences in Inhibitory Control and Working Memory

MANCOVA revealed a significant main effect of group on inhibitory control and working memory, Wilks' λ = .82, $F(3,68)$=5.06, p=.003. Age at adoption group by age at assessment interaction effects were not significant and therefore were omitted from the final analysis of variance. Univariate analyses indicated that PI children adopted ≥ 14 months recalled significantly fewer items on the spatial span task and had a significantly higher SSRT relative to PI children adopted ≤ 9 months, but there were no significant group differences for the spatial working memory task (see Table 2)[1].

[1]We re-ran analyses after removing 11 children taking stimulant medications on the day of testing. The multivariate analysis indicated significant PI group differences, Wilks' λ = .85, $F(3,57)$ = 3.24, p=.03, but univariate analyses revealed that only the spatial span task remained significant, $F(1,59)$=6.68, p=.01, d=.67. Group differences on the spatial span task among older-adopted PI, younger-adopted PI, and NA children remained significant, $F(2,189)$=6.93, p=.001. The older-adopted PI group had lower spatial span relative to the younger-adopted PI and the NA groups (d=.61), which did not differ significantly. Similarly, PI group differences in parent-rated attention problems remained significant. Older-adopted PI children had higher levels of inattention, $t(61)$=3.43, p=.001, d=.86, and hyperactivity-impulsivity, $t(46)$=2.40, p=.02, d=.67, than younger-adopted PI children.

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Spatial Span Task: Comparison to Non-Adopted Children

ANCOVA revealed a significant main effect of group on spatial span length, $F(2,201) = 8.83$, $p<.001$. Pairwise comparisons indicated that the older-adopted PI group (M=5.65, SD=1.56) had a significantly lower span length than both the younger-adopted PI group (M=6.69, SD=1.61) and the NA group (M=6.51, SD=1.61), which did not differ significantly from each other. Cohen's d for the significant difference between the older-adopted PI and NA groups was .54, a moderate effect.

Birth Circumstances and Inhibitory Control and Working Memory

As shown in Table 1, there were no significant PI group differences in birth weight or the percentage of children born prematurely. PI children born and not born prematurely did not differ significantly on the inhibitory control or working memory measures, $t(56) = .42–1.33$, *ns*. Similarly, there were no significant correlations between continuously-scaled birth weight and inhibitory control or working memory measures, r=.08–.18, *ns*. Categorical analyses of birth weight revealed that children with LBW had significantly more spatial working memory task total errors, $t(49) = 2.30$, $p<.05$, n=51, but did not have significantly poorer performance on the stop-signal, $t(48) = .97$, *ns*, or spatial span tasks, $t(49) = 1.41$, *ns*, than children with birth weights in the normal range.

PI Group Differences in Parent-Rated Attention Problems

PI children adopted ≥ 14 months had significantly higher T scores on the Inattentive and Hyperactive-Impulsive scales than those adopted ≤ 9 months (see Table 2) and the CPRS normative sample, one-sample $t(34)$=3.88–5.42, $p<.001$. PI children adopted ≤ 9 months did not differ significantly from the normative sample on the Inattentive or Hyperactive-Impulsive scales, one-sample $t(37)$=.67–1.68, *ns*.

Inhibitory Control, Working Memory, and Parent-Rated Attention Problems

As shown in Table 3, SSRT and spatial span length were significantly correlated with Hyperactive-Impulsive scale T scores (correlation with spatial working memory total errors was marginally significant), but none of the task scores were significantly associated with Inattentive scale T scores. We re-ran analyses examining associations with Hyperactive-Impulsive scores using Spearman's rank correlation coefficient. Similar to Pearson correlation results presented in Table 3, Hyperactive-Impulsive scale scores were correlated significantly with spatial span length, $r_s = -.23$, $p<.05$, spatial working memory task total errors, $r_s = .24$, $p<.05$, and SSRT, $r_s = .28$, $p<.05$.

It was important to ensure that the relations between task performance and parent-rated hyperactivity-impulsivity were not a result of age at adoption or age at assessment. In multiple linear regression analyses, hyperactivity-impulsivity was regressed on age at adoption group and age at assessment (entered first) and SSRT/spatial span length/spatial working memory total errors (entered second). In the first regression analysis, at the first step, age at adoption group and age at assessment accounted for a significant amount of the variability in hyperactivity-impulsivity, $R^2 = .09$, $F(2,69) = 3.30$, $p = .04$. At the second step, SSRT did not account for a significant amount of variability in hyperactivity-impulsivity after controlling for age at adoption group and age at assessment, $\Delta R^2 = .03$, $F(1,68) = 2.44$, $p = .12$. In the second regression analysis, at the second step, spatial span length accounted for a significant amount of variability in hyperactivity-impulsivity even after controlling for age at adoption group and age at assessment, $\Delta R^2 = .05$, $F(1,70) = 4.36$, $p = .04$. In the third regression analysis, at the second step, spatial working memory total errors accounted for a significant amount of variability in hyperactivity-impulsivity after

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controlling for age at adoption group and age at assessment, $\Delta R^2 = .07$, $F(1,70) = 5.60$, $p = .02$.

Discussion

The purpose of this study was to investigate inhibitory control and working memory among 8- to 17-year-old post-institutionalized (PI) children. Findings revealed that PI children adopted after 14 months showed poorer performance on the stop-signal and spatial span tasks compared to those adopted before 9 months after controlling for age at assessment. There were no significant group differences on the spatial self-ordered search task. Older-adopted PI children also showed poorer spatial span task performance relative to children reared in their birth families, but younger-adopted PI children did not. Effect sizes for the significant group differences were generally in the moderate range.

These findings suggest that older-adopted PI children may have difficulty suppressing an already-initiated motor response and maintaining visual-spatial items in mind over short periods of time. Findings for the spatial self-ordered search task contrast previous studies of older-adopted PI children that have indicated deficits on this task (e.g., Bauer et al., 2009). Our PI sample was older at assessment and included adolescents, and it is possible that they used compensatory strategies on this task. Therefore, further studies are required to tease apart any specific difficulties PI children may be having within the domain of spatial working memory.

Poor performance on these inhibitory control and working memory tasks is consistent with the idea that prolonged early institutional deprivation may disrupt the development of fronto-striatal networks. More specifically, in typical development, the stop-signal and spatial span tasks recruit prefrontal cortex as well as inferior parietal cortex, anterior cingulate cortex, basal ganglia, and cerebellum, which show differential recruitment with age until adulthood (Geier, Garver, Terwilliger, & Luna, 2009; Velanova, Wheeler, & Luna, 2009; see review, Luna, 2009). PI children's difficulties with these tasks are consistent with animal models of early deprivation (Sanchez, Ladd, & Plotsky, 2001) and human neuroimaging studies showing links between early adverse care and structural and functional changes in fronto-striatal circuitry (Hart & Rubia, 2012; Nelson, Bos, Gunnar, & Sonuga-Barke, 2011). Further study of neural activation while performing core executive tasks would reveal the brain regions that PI children rely on to execute goal-directed behavior and how the maturation of neural processes may differ for PI children relative to typically-developing children.

The PI children in this study were adopted from less severely depriving institutions than those represented in previous studies. Their institutions of origin tended toward the level of psychosocial deprivation, which generally refers to institutions that provide adequate physical resources but fail to provide a consistent set of responsive caregivers. Given these sample characteristics, it is possible that inhibitory control and working memory difficulties may be associated with early exposure to psychosocial deficiencies of institutions even under circumstances in which other institutional inadequacies are less likely to be present. This interpretation would be consistent with studies indicating that caregiver responsiveness and scaffolding support the early development of executive functioning (Bernier, Carlson, & Whipple, 2010) and that early adverse care is associated with executive function difficulties (Pears et al., 2010). However, it is possible that these PI children were exposed to other institutional deficiencies that could have contributed to their executive function difficulties.

While PI children often show developmental catch-up following adoption, the potential for recovery may vary depending on the timing or duration of institutional exposure. The

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current study suggests that exposure for at least the first 14 months of life may result in later executive function difficulties, whereas removal from the institution prior to 9 months of age may not be associated with an increased risk of later difficulties. This adds to previous literature that only examined older-adopted PI children by specifying the age or length of exposure associated with developmental recovery.

The PI children in our sample were adopted into families characterized by high parental education and income, and the PI groups did not differ in these adoptive family characteristics. Therefore, post-adoption environmental differences may not have contributed to group differences in executive functioning. Although birth circumstances did not differ significantly between the PI groups, low birth weight was significantly associated with poorer spatial working memory. These birth data were not available for 39% of the PI sample and were provided by adoptive parents. Therefore, although there was some indication that prematurity and birth weight may not explain PI group differences in executive functioning, future studies of PI children should continue to explore the potential role of birth circumstances.

As expected, older-adopted PI children had significantly higher levels of parent-rated inattention and hyperactivity-impulsivity, ADHD symptoms, than both younger-adopted PI children and children in the standardization sample who did not differ. Given the results for clinical range scores, at least a third of the older-adopted PI children were potentially displaying attention problems similar to ADHD. Further research is needed that directly compares PI children and children with ADHD who do not have histories of early institutional deprivation (Sonuga-Barke & Rubia, 2008).

Heightened parent-rated hyperactivity-impulsivity but not inattention was significantly associated with poorer inhibitory control and working memory task performance, and the association with spatial working memory remained significant after accounting for age at adoption. It is possible that parents may more accurately report on hyperactive-impulsive behaviors because these are more easily observed or that the Inattentive scale may have captured a broader set of inattentive behaviors, with varying causes and correlates. Nonetheless, these results suggest that group differences in inhibitory control and working memory task performance may reflect meaningful differences in PI children's level of hyperactivity-impulsivity in everyday settings. Similar to studies of children with ADHD (Crosbie et al., 2008; Nigg, 1999), in this study of PI children, increased ADHD symptoms were associated with poorer executive functioning. This finding highlights the need mentioned above for studies comparing these groups.

These findings imply that PI children adopted at older ages should be evaluated early for executive function and attention regulation difficulties. For those who do demonstrate these problems, targeted interventions may prevent problems from worsening or affecting other developmental domains as well as academic performance. For children who reside in institutions, the provision of relationships with responsive caregivers may be essential to executive function and attention regulation development. Interventions provided in institutions as well as placement in family care often represent an improvement in psychosocial conditions.

This study had a number of limitations. The sample size was small but within the range of studies using neurocognitive measures. Children spanning a wide range of age at assessment were included in the study to allow us to recruit enough children for both age at adoption groups. Like other studies of internationally adopted PI children, this study could not completely rule out the influence of potential confounding risk factors, such as genetics and prenatal care. Similarly, factors other than exposure to early institutional deprivation may

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have differentiated the PI and non-adopted (NA) groups and possibly contributed to group differences in spatial working memory. In addition, differences in testing conditions (e.g., different examiners, testing contexts, levels of fatigue) between the PI and NA groups could also have influenced results.

Because this PI sample was adopted solely from Russia or the former Soviet Union, the results may not be representative of children adopted from institutions worldwide. In particular, children adopted from this region may have an increased likelihood of prenatal alcohol exposure (PAE), which is linked with executive function deficits in children without institutional backgrounds (Rasmussen & Bisanz, 2009). This study excluded PI children with parent-reported professional diagnoses of FASD. Prior studies also included PI children adopted from other areas of the world (e.g., Asia, Latin America) and/or excluded children with facial indicators of PAE and still found executive function deficits (Bauer et al., 2009; Bos et al., 2009; Pollak et al., 2010). Another limitation is that some PI children took stimulant medication on the day of testing, although this did not differ significantly between PI groups. In addition, although few PI children were taking other psychoactive medications, it is also possible that these medications influenced task performance. Children with psychiatric diagnoses were not excluded from the PI group but were excluded from the NA group, and therefore psychiatric diagnoses confound PI-NA comparisons and perhaps older- and younger-adopted PI comparisons.

While the attribution of age at adoption effects to the selective adoption of healthier children at younger ages cannot be ruled out in the current study, prior study designs, such as those of the BEIP and ERA studies, suggest that selective adoption is unlikely to explain age at adoption effects (Fox, Almas, Degnan, Nelson, & Zeanah, 2011; Rutter et al., 2007). For the few PI children who spent some pre-adoption time with their birth families, we did not have data on the age at which this occurred.

Findings from this study suggest that older-adopted PI children have an increased risk of persistent difficulties with inhibitory control and working memory, while younger-adopted PI children may not differ significantly from typically-developing children. Poorer performance on inhibitory control and working memory tasks may be associated with heightened hyperactivity-impulsivity in everyday contexts. Based on these findings, future studies should use neuroimaging techniques to examine early deprivation effects on frontal-striatal networks. In a clinical setting, PI children may benefit from early evaluations tapping specific aspects of executive function and interventions targeting the improvement of these skills.

Acknowledgments

This research was supported by NICHD grants HD39017 and HD050212 to Robert B. McCall and Christina J. Groark. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NICHD or NIH. The authors thank Larisa Mason, Mary Graber, Larry Fish, Johana Rosas, Megan Julian, and Brandi Hawk for assistance in implementing this study. The authors are especially grateful to the parents and children who participated in this study.

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Table 1

Descriptive statistics for child and family characteristics

	Age at adoption (months)		
	≤9 (*n*=41)	**≥14 (*n*=34)**	**Statistical test**
Age (years)	13.10 (2.53)	12.82 (3.57)	$t(58) = .38$, *ns*
% Male	39%	38%	$\chi^2(1, N=75) = .01$, *ns*
Country of origin	Russia (36) Ukraine (1) Belarus (2) Uzbekistan (2)	Russia (29) Belarus (4) Uzbekistan (1)	
Time in an institution (months)	7.28 (1.48)	19.97 (8.10)	$t(35)=9.01$, $p<.001$
Time in adoptive home (years)	12.45 (2.53)	10.77 (3.54)	$t(58)=2.31$, $p<.05$
IQ[a]	107.51 (10.01)	99.53 (12.44)	$F(1,73)=9.48$, $p<.01$
% taking stimulant meds day of assessment	15%	15%	$\chi^2(1, N=75) = .00$, *ns*
% born prematurely	39%	38%	$\chi^2(1, N=57) = .00$, *ns*
Birth weight (lbs)	6.11 (1.63)	5.71 (1.57)	$t(49)=.84$, *ns*
% LBW (< 5.5 lbs)	33%	39%	$\chi^2(1, N=51) = .16$, *ns*
Parent marital status (%married/partnered)	90%	82%	$\chi^2(1, N=75) = .84$, *ns*
Parent education (% with 4-year college degree)	95%	94%	$\chi^2(1, N=75) = .01$, *ns*
Household income (%earning > $100,000)	79%	74%	$\chi^2(1, N=75) = .22$, *ns*

[a]Estimated based on the Vocabulary and Matrix Reasoning subtests of the WISC-IV

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Table 2

Inhibitory control, working memory, and attention problems in post-institutionalized children adopted ≤ 9 months and ≥ 14 months

	Age at adoption (months)			
	≤9 (*n*=41)	**≥14 (*n*=34)**		
	***M* (*SD*)**	***M* (*SD*)**	**Statistical test**	***d***
CANTAB tasks				
Spatial working memory (total errors)	32.13 (17.09)	34.88 (18.58)	$F(1,70)=.16$, $p=.69$	.16
Spatial span (span length)	6.69 (1.61)	5.65 (1.56)	$F(1,70)=8.69$, $p=.004$	.65
Stop-signal reaction time (ms)	199.26 (65.84)	246.04 (93.01)	$F(1,70)=5.71$, $p=.02$	.58
CPRS				
Inattentive *T* score	53.48 (11.79)	**61.50** (13.40)	$t(72)=2.83$, $p=.01$	.64
% in clinical range	18%	44%	$\chi^2(1, N=74)=6.23$, $p=.01$	--
Hyperactive-Impulsive *T* score	51.48 (8.37)	**58.47** (14.08)	$t(56)=2.43$, $p=.02$	.60
% in clinical range	13%	29%	$\chi^2(1, N=74)=3.25$, $p=.07$	--

Note. Analyses of task scores control for age at assessment. Bolded means are significantly higher than the CPRS standardization sample mean of 50 (*SD*=10); CANTAB = Cambridge Neuropsychological Test Automated Battery; CPRS = Conners' Parent Rating Scale

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Table 3

Bivariate correlations among inhibitory control, working memory, inattention, and hyperactivity-impulsivity

	1	2	3	4	5
1 Spatial span (span length)	--				
2 Spatial working memory (total errors)	−.50***	--			
3 Stop-signal reaction time (ms)	−.19	.28*	--		
4 CPRS Inattentive *T* score	−.14	.15	.21+	--	
5 CPRS Hyperactive-Impulsive *T* score	−.24*	.20+	.25*	.57***	--

+ $p<.10$;

* $p<.05$;

** $p<.01$;

*** $p<.001$

Note. ms = milliseconds; CPRS = Conners' Parent Rating Scale