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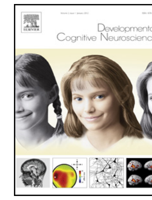

Normalization of EEG activity among previously institutionalized children placed into foster care: A 12-year follow-up of the Bucharest Early Intervention Project

Ross E. Vanderwert[a,*], Charles H. Zeanah[b], Nathan A. Fox[c], Charles A. Nelson III[d,e,f]

[a] School of Psychology, Cardiff University, 70 Park Place, Tower Building, Cardiff CF10 3AT, United Kingdom
[b] Tulane University, New Orleans, LA, United States
[c] University of Maryland, College Park, MD, United States
[d] Boston Children's Hospital and Harvard Medical School, Boston, MA, United States
[e] Harvard Graduate School of Education, Cambridge, MA, United States
[f] Harvard Center on the Developing Child, Cambridge, MA, United States

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ABSTRACT

Extreme social and cognitive deprivation as a result of institutional care has profound effects on developmental outcomes across multiple domains for many abandoned or orphaned children. The Bucharest Early Intervention Project (BEIP) examines the outcomes for children originally placed in institutions who were assessed comprehensively and then randomized to foster care (FCG) or care as usual (CAUG) and followed longitudinally. Here we report on the brain electrical activity (electroencephalogram: EEG) of 12-year-old children enrolled in the BEIP. Previous reports suggested improvement in resting EEG activity for the group of children placed in the foster care intervention, particularly those placed before 24 months of age compared to children who were randomized to CAUG or those placed into families after this age. At 12 years, differences between those in the FCG and those in the CAUG persist in the alpha band (8–13 Hz), but not in higher frequency bands (i.e. in the beta band; 15–30 Hz), except in those children placed into the FCG who remained in high quality care environments over the course of the study. These findings highlight the importance of maintaining a stable high quality caregiving environment, particularly for children exposed to early psychosocial deprivation, for promoting healthy brain development.

1. Introduction

The use of institutional care for abandoned or orphaned infants and children has remained a common practice throughout the world (Browne et al., 2006; UNICEF, 2015); however, institutional environments are harmful for healthy physical and psychological development especially for young children. Many institutions have high child-to-caregiver ratios, have highly regimented schedules with extended periods where children are left alone, and very little engagement with the caregivers (Castle et al., 1999; Nelson, 2007; Smyke et al., 2007). The consequences of these rearing conditions often include physical growth restriction, a wide range of behavioral problems, and deficits in cognitive function compared to children raised in families (Maclean, 2003; Nelson, 2007; for review, see Nelson et al., 2014).

Extreme deprivation dramatically alters neural architecture and functioning. A number of neuroimaging studies have examined the impact of those early experiences in post-institutionalized adoptees. For example, structural magnetic resonance imaging (MRI) studies have shown decreased grey and white matter volumes (Mehta et al., 2009; Sheridan et al., 2012), increased amygdala volume (Mehta et al., 2009; Tottenham et al., 2010), decreased cerebellar volumes (Bauer et al., 2009), and disrupted connectivity between the frontal and temporal lobes (Eluvathingal et al., 2006) in previously institutionalized children compared to community controls. Together these studies demonstrate that typical neural development is altered as a result of early deprivation. However, fewer studies have examined the impact of intervention and tracked changes in brain development as a result of removal from institutions.

* Corresponding author. Tel.: +44 0 29 2087 0467.
E-mail address: VanderwertR@cardiff.ac.uk (R.E. Vanderwert).

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The BEIP is the first study to experimentally examine the physical, psychological, and neural sequelae of institutional rearing and the developmental trajectories of children removed and placed into a novel foster care intervention (Smyke et al., 2009; Zeanah et al., 2003). A group of infants living in institutions as well as an age-matched community control sample (never institutionalized group; NIG) all living in Bucharest, Romania were recruited into the study. After an initial screening to exclude for genetic disorders or other medical conditions the infants completed a baseline assessment, including resting EEG. The infants were then randomly assigned to either remain in the institution (care as usual; CAUG) or placed with a foster family (FCG). Random assignment of these children provides an opportunity to examine the effects of the intervention and repeated assessments over the children's life have allowed examination of changes in development associated with enrichment of their early care environment. Greater detail regarding the study design and ethical issues are described elsewhere (Miller, 2009; Millum and Emanuel, 2007; Zeanah et al., 2012).

Previous reports from this study found at the baseline assessment, infants living in institutions showed markedly decreased power in both alpha and beta activity and increased theta power compared to the never institutionalized community controls (Marshall, Fox and the BEIP core group, 2004). The pattern of higher theta and lower alpha power is one that is associated with attention-deficit/hyperactivity disorder (ADHD) and other learning disorders (Barry et al., 2003, 2009; Chabot et al., 2005; McLaughlin et al., 2010), the former being highly prevalent among previously institutionalized children (Bos et al., 2011; Kreppner et al., 2001; Wiik et al., 2011; Zeanah et al., 2009).

Following placement into foster care, EEG was again collected when the children were 42 months. The mean age of placement for the foster care group was 22 months. At the 42 month assessment there was a hint that earlier placement into foster care was beneficial, as infants placed at younger ages showed increasing alpha power relative to older placed infants (Marshall et al., 2008). The effect of timing of placement in foster care became clear by the time the children were 8-years-old; infants placed into foster care before 24 months were indistinguishable from children in the community while those placed after 24 months were identical to the CAUG (Vanderwert et al., 2010). Further, age of removal from institutions also significantly impacted the developmental trajectories of alpha and beta power between 42-months and 8-years (Stamoulis et al., 2015) suggesting ongoing plasticity in beta rhythm that was not detected in the follow-up at 8 years.

The aim of this study is to examine the continuing effects of foster care intervention on the neural activity of children removed from institutions in infancy. For the current study, resting EEG activity was acquired when children in the BEIP study were 12 years of age. Our primary hypothesis was that the intervention effects observed in the alpha band when the children were 8 years old would persist to the current assessment and that the intervention would also improve power in the beta band in the FCG compared to the CAUG. We also wanted to examine whether timing effects of the intervention (i.e., age at placement into foster care) would affect the pattern of alpha and beta activity.

We conducted two additional exploratory analyses. First, following up a recent examination of the developmental trajectories of the EEG from children in the BEIP study (Stamoulis et al., 2015), we also wanted to examine continuing changes in the three frequency bands between ages 8- and 12-years. Second, over the duration of the BEIP study some of the children in the FCG have experienced disruptions to their caregiving environment. Recently, Humphreys et al. (2015) found that children in stable placement in foster care had fewer internalizing and externalizing symptoms compared to those with unstable placements. Therefore, we also examined the effects of stability of placement on the EEG.

2. Methods

2.1. Sample

At the 12-year assessment, EEG was collected on 50 (26 male) children from the FCG, 49 (27 male) children in CAUG, and 48 (22 male) children from the NIG. The three groups did not differ on gender, $\chi^2(2, N = 147) = .863$, $p = .65$; or on age at data collection ($M = 12.60$, SD = .54; $F(2, 146) = .324$, $p = .724$). A number of children were excluded from analyses due to an excessive number of bad channels or too few artifact free epochs (>6 channels; $N = 3$ CAUG, 3 FCG, 2 NIG); the task not being completed due to equipment failure or subject non-compliance ($N = 1$ CAUG, 1 FCG); medication use ($N = 7$ CAUG, 5 FCG); or with EEG data exceeding ± 2 SD from the group mean in either absolute or relative power at multiple electrode clusters across the scalp, in multiple frequency bands, or meeting both these criteria ($N = 5$ CAUG, 3 FCG, 5 NIG). Of the original sample, 19 CAUG, 17 FCG, and 40 NIG children were unavailable for testing (Table 1).

The University Institutional Review Boards of the principal investigators (Fox, Nelson, and Zeanah) and of the University of Bucharest approved the study protocol. Romanian law dictates that consent be given by the legal guardian of each child, therefore in the cases where consent was unavailable, assent was obtained from each caregiver who accompanied a child to the visit and from each child.

2.2. EEG recording & analysis

Continuous EEG was recorded using a 64-channel HydroCel Geodesic Sensor Net (Electrical Geodesic Inc., Eugene, OR) that was connected to a NetAmps 300 amplifier (Electrical Geodesic Inc., Eugene, OR) and referenced online to a single vertex electrode (Cz). Channel impedances were kept at or below 50 kΩ and signals were sampled at 500 Hz. The child's head circumference was measured and an appropriately sized net was fitted. EEG was recorded while the children sat quietly in a chair, alternating 1-min epochs of eyes open and eyes closed for a total of 6 min. During the eyes open

Table 1
Continuity of participants from the 8-year to 12-year wave of assessments.

Group	Assessed at 8 yr & 12 yr	Assessed at 8 yr not 12 yr	Assessed at 12 yr not 8 yr	Missing at 8 yr & 12 yr	Mean (SD) Placement age
CAUG	42	6	7	13	–
FCG	45	8	5	9	22.62 (7.01)
Stable	21	0	3	2	21.50 (7.15)
Disrupted	24	2	1	1	23.81 (6.95)
NIG	29	13	19	27	–

Note. There are no differences between groups in the number of children assessed or missing at 8-year or 12-year waves. There are no differences in age of placement into the intervention between the FCG-Stable and FCG-Disrupted.