Published in final edited form as:

Neuroimage. 2009 August ; 47(Suppl 2): T66–T71. doi:10.1016/j.neuroimage.2009.03.005.

Reduced Prefrontal Cortical Gray Matter Volume in Young Adults Exposed to Harsh Corporal Punishment

Akemi Tomoda, MD, PhD^{1,2,3}, Hanako Suzuki, MA^{2,3}, Keren Rabi, MA², Yi-Shin Sheu, BS², Ann Polcari, PhD^{1,2}, and Martin H. Teicher, MD^{1,2}

¹ Department of Psychiatry, Harvard Medical School, Boston, MA, USA

² Developmental Biopsychiatry Research Program, McLean Hospital, Belmont, MA

³ Department of Child Developmental Sociology, Faculty of Medical and Pharmaceutical Sciences, Kumamoto University, Kumamoto, Japan

Abstract

Objective—Harsh corporal punishment (HCP) during childhood is a chronic, developmental stressor associated with depression, aggression and addictive behaviors. Exposure to traumatic stressors, such as sexual abuse, is associated with alteration in brain structure, but nothing is known about the potential neurobiological consequences of HCP. The aim of this study was to investigate whether HCP was associated with discernible alterations in gray matter volume (GMV) using voxel-based morphometry (VBM).

Methods—1,455 young adults (18–25 years) were screened to identify 23 with exposure to HCP (minimum 3 years duration, 12 episodes per year, frequently involving objects) and 22 healthy controls. High-resolution T1-weighted MRI datasets were obtained using Siemens 3T trio scanner.

Results—GMV was reduced by 19.1% in the right medial frontal gyrus (medial prefrontal cortex; MPFC, BA10) ($P = 0.037$, corrected cluster level), by 14.5% in the left medial frontal gyrus (dorsolateral prefrontal cortex; DLPFC, BA 9) ($P = 0.015$, uncorrected cluster level) and by 16.9% in the right anterior cingulate gyrus (BA 24) ($P < 0.001$, uncorrected cluster level) of HCP subjects. There were significant correlations between GMV in these identified regions and performance IQ on the WAIS-III.

Conclusions—Exposing children to harsh HCP may have detrimental effects on trajectories of brain development. However, it is also conceivable that differences in prefrontal cortical development may increase risk of exposure to HCP.

Keywords

corporal punishment (CP); harsh corporal punishment (HCP); voxel-based morphometry (VBM); gray matter volume (GMV); medial prefrontal cortex (MPFC); dorsolateral prefrontal cortex (DLPFC); anterior cingulate gyrus (AC); MRPFC (medial rostral prefrontal cortex)

INTRODUCTION

Corporal punishment (CP) has been defined as “the use of physical force with the intention of causing a child to experience pain but not injury for the purpose of correction or control of the

Correspondence address: Akemi Tomoda, MD, PhD, Department of Child Developmental Sociology, Faculty of Medical and Pharmaceutical Sciences, Kumamoto University, 1-1-1 Honjo, Kumamoto, 860-8566, Japan, tomo@kumamoto-u.ac.jp, Fax: +81-96-373-5200, Tel: +81-96-373-5196.

child's behavior" (Straus et al., 1997). However, such discipline (or its excessive use) has been considered as a type of child maltreatment and has been identified as having various negative psychological and physiological consequences. A history of exposure to severe CP is reportedly associated with aggression, delinquency (Gershoff, 2002), antisocial and violent behaviors (Ambati et al., 1998; Ohene et al., 2006; Slade and Wissow, 2004; Straus et al., 1997), depression (Banks, 2002; Straus and Kantor, 1994), suicidal behavior (Straus and Kantor, 1994), and other psychiatric disorders such as PTSD (Medina et al., 2001) and substance abuse (Lau et al., 2005). Furthermore, CP is related to the intergenerational transmission of intimate partner and family violence (Deater-Deckard et al., 2003; Muller et al., 1995; Schwartz et al., 2006) and is associated with risk of being victim of physical abuse and risk of abusing one's own child or spouse (Gershoff, 2002).

Exposure to various forms of childhood abuse, including physical abuse, sexual abuse and neglect have been associated with alterations in brain structure (e.g., (Andersen et al., 2008; Bremner et al., 1997; De Bellis et al., 1999; De Bellis et al., 2002; De Bellis and Kuchibhatla, 2006; Richert et al., 2006; Teicher et al., 2004; Teicher et al., 1997)). Diffusion tensor differences have also been observed in young adults with high-level exposure to parental verbal abuse (Choi et al., 2008).

Is exposure to parental CP a sufficiently severe developmental stressor to be associated with discernible effects on brain morphometry? To address this question we chose to examine exposure to a form of CP that is widely considered to be excessive and unacceptable. The American Academy of Pediatrics (AAP) considers spanking with an open hand for the purpose of behavior modification to be an acceptable form of punishment. However, this form of punishment becomes unacceptable if it involves use of an object, extends to regions beyond buttocks and extremities, is conducted out of anger, or results in injury. We defined harsh CP (HCP) as a severe form of CP, in which an object (e.g., belt, paddle, hair brush) was used on occasion for the purpose of disciplining a child, provided it did not extend beyond the buttocks, was not conducted out of anger, and did not result in injury. We focused on HCP rather than ordinary CP, which is much more common, hypothesizing that HCP would be associated with a stronger signal and more discernible effects. If associations emerged between imaging findings and HCP it would justify studies in a larger group of subjects exposed to ordinary CP.

This study was designed to evaluate GMV using an unbiased, whole-brain, voxel-by-voxel approach in a non-clinical sample of late adolescents/young adults exposed to HCP during childhood. Our sample was screened to exclude extraneous factors (e.g., substance abuse, head injury, fetal drug exposure, exposure to physical, sexual or emotional abuse) that might have influenced brain development. We hypothesized that exposure to childhood HCP might alter the developmental trajectory of brain regions involved in regulating emotion, aggression, attention, and cognition.

PARTICIPANTS AND METHODS

1. Participants and procedure

The McLean Hospital Institutional Review Board approved all procedures. Participants in the study were recruited from the community through an advertisement entitled "Memories of Childhood". Screenings were conducted on 1,455 volunteers using a detailed online assessment instrument with 2,342 entry fields that provided a vast array of information regarding childhood history, development, and symptomatology. The questionnaire also included demographic information, such as subjects' and parents' educational levels, annual household income, and race/ethnicity. In addition, a scale was included to assess subjects' perception of financial stress while they were growing up. Known as '*perceived financial sufficiency*' and based on a 5-point Likert scale, subjects rated their family's financial situation while growing up, which ranged

from 1 (much less than enough money for our needs), to 5 (much more enough money for our needs). Subjects provided written informed consent prior to completing the online instrument, and again before interviews and imaging.

Eligible subjects were invited for three visits. The first visit constituted a face-to-face interview to elicit subjects' developmental history and history of psychiatric disorders using Structured Clinical Interviews for DSM-IV Axis I and II Disorders (SCID-I, II) (First et al., 1997). The second visit consisted of standardized psychometric testing such the Wechsler Adult Intelligence Scale III (WAIS-III) (Wechsler, 1997), the Woodcock-Johnson Test, and the Memory Assessment Scale (Golden et al., 1999). Finally, we recruited 45 individuals (23 subjects with CP and 22 controls) for MRI evaluation.

The HCP group contained 23 young adults (15 males, 8 females; mean age, 21.7 years, SD, 2.2 years) with a history of exposure to CP in early childhood (Table 1) that occasionally involved use of objects. The control group comprised 22 young adults (6 males, 16 females; mean age, 21.7 years; SD, 1.8 years) with neither a current nor past DSM-IV-TR Axis I disorder (based on the SCID-I). Controls had no history of abuse nor exposure to traumatic events, HCP, or more than minimal exposure to ordinary CP. Subjects were excluded who had any history of substance abuse, any recent substance use, head trauma with loss of consciousness, significant fetal exposure to alcohol or drugs, perinatal or neonatal complications, neurological disorders, or medical conditions that might adversely affect growth and development. All participants were right-handed and unmedicated. HCP and controls were matched as closely as possible for degree of alcohol and substance use.

2. Measure

2.1. Harsh Corporal punishment and other trauma—History of exposure to CP was obtained using the Life Experiences Questionnaire (LEQ) as part of the on-line assessment and through the face-to-face interview. The LEQ consisted of 34 items that screen for exposure to traumatic events in general (e.g., witnessing gang violence, nearly drowning). Questions about parental CP are included in this questionnaire (e.g., “*Have you ever been punished with spankings from your parents’ open hand?*” “*Have you ever been punished with spankings with a belt, paddle, or stick?*”). The LEQ was used to identify potential subjects. Degree of exposure was evaluated through a detailed semi-structured interview, which explored the ways in which they were disciplined throughout childhood. The criteria for inclusion in the HCP group was CP that began prior to their 12th birthday and lasted for at least 3 years, with a frequency of about 12 episodes or more per year. Additionally, an object such as belt, strap, hairbrush, or paddle was used for punishment more or less annually. HCP subjects must have experienced these punishments from a primary disciplinarian who was a custodial adult. Subjects who either had never received CP or had only minimal exposure, and were never struck with objects were classified into the control group. Moreover, we were careful to exclude instances of physical abuse, emphasizing that CP had to occur specifically for discipline, with parents in emotional control, and not striking out in anger. Any intentional injury that received, or should have received medical attention, or left a scar was considered abuse. So was any painful physical contact other than to the buttocks or extremities, save potentially for a rare open handed slap to the face. A panel of three doctoral-level psychiatric clinicians with extensive experience treating children, who were blind to any of the neuroimaging results, reviewed the disciplinary history of each subject. Assignments were made to groups by full consensus.

History of exposure to no other forms of abuse were confirmed using the semi-structured Traumatic Antecedents Interview (Herman et al., 1989). Exposure to childhood verbal abuse was assessed with the Parental Verbal Aggression Scale (PVAS). Subjects with PVAS scores ≥ 40 , indicative of exposure to substantial and deleterious levels verbal abuse (Teicher et al., 2006), were excluded.

2.2. Psychiatric symptoms and well-being—Self-report ratings of dissociation, ‘limbic irritability’, depression, anxiety and anger-hostility were obtained using the Dissociative Experience Scale, (Bernstein and Putnam, 1986) limbic system checklist – 33 (LSCL-33) (Teicher et al., 1993), and Kellner’s Symptom Questionnaire (Kellner, 1987), respectively. Scores on these scales are elevated by exposure to other forms of childhood stress (Teicher et al., 2006), and have been found in previous studies to correlate with regional alterations in structure or function associated with maltreatment (Anderson et al., 2002; Choi et al., 2008). Hence, we used these ratings in an exploratory manner to delineate potential functional correlates of regions of reduced GMV.

3. MRI acquisition and analysis

Image analysis was performed on high-resolution T1-weighted MRI datasets, which were acquired on a Trio Scanner (3 T; Siemens AG). An inversion prepared 3D MPRAGE sequence was used with an eight-element phased-array RF reception coil (Siemens AG). The GRAPPA acquisition and processing was used to reduce the scan time, with a GRAPPA factor of 2. Scan parameters were: the sagittal plane, TE/TR/TI/flip = 2.74 ms/2.1 s/1.1 s/12 deg; 3D matrix $256 \times 256 \times 128$ on $256 \times 256 \times 170$ mm field of view; bandwidth 48.6 kHz; scan time 4:56.

VBM was performed using SPM5 for imaging processing (MATLAB 6.5; The MathWorks Inc., Natick, MA, USA). As a fully automated whole-brain morphometric technique, VBM detects regional structural differences between groups on a voxel-by-voxel basis (Good et al., 2001a; Good et al., 2001b). Briefly, images were segmented into gray matter, white matter, cerebrospinal fluid, and skull/scalp compartments, then normalized to standard space and re-segmented. Any volume change that was induced by normalization was adjusted. The spatially normalized segments of gray and white matter were smoothed using a 12-mm full-width half-maximum isotropic Gaussian kernel. Statistical analysis of regional differences between groups was performed using a permutation test for decreased probability of a particular voxel containing gray or white matter. Potential confounding effects of age, gender, score on the PVAS, parental education, perceived financial sufficiency, and whole segment GMV were modeled. Variances attributable to them were excluded from analyses. The significance levels for statistics estimated by permutation tests were set at $P = 0.05$, corrected for multiple comparisons.

4. Statistical analysis

Significant sociodemographic differences between HCP and control group complicated the exploration of post-hoc functional correlates between VBM identified regions with significantly reduced GMV, and symptom ratings and IQ measures. Hence, multiple regression analysis was used to assess whether there were statistically significant associations (standardized beta weights and overall r -value) between GMV in identified regions and ratings, taking into account differences attributable to gender, parental education and perceived financial sufficiency. Multiple regression analysis was performed on the entire sample, as there were no significant group differences on most measures of interest. When a significant association was found, we also ascertained whether it was present in the HCP group alone, to help assure that the relationship was not an artifact of group differences. This approach reduced the number of cross-correlations examined by a factor of three. A multiple regression r value ≤ 0.01 was required for significance, to compensate for the number of tested associations. Statistical analyses were performed using SPSS statistical software (SPSS Inc., Chicago, IL).

RESULTS

HCP subjects reported mean duration of exposure to CP of 8.5 ± 3.5 years. Thirty-six percent of controls had limited exposure to ordinary CP, with an average exposure duration of 1.8 ± 3.0

years. Average age of onset and offset of CP in the HCP group was 3.9 ± 2.3 and 11.4 ± 2.5 years, respectively. HCP began almost concurrently with CP (4.2 ± 2.3 years). Subjects in the HCP group were predominantly male (65%), whereas controls were predominantly female (73%; Table I). Parents of HCP subjects had, on average, two years less education than parents of controls ($P = 0.004$), and HCP subjects experienced a somewhat greater degree of financial stress growing up ($P = 0.01$). HCP subjects were exposed to significantly higher levels of parental verbal aggression than controls ($P < 0.0001$), though no subjects were exposed to levels that we had previously defined as abusive (Choi et al., 2008; Teicher et al., 2006). Differences in gender ratio, parental education, perceived financial stress and exposure to parental verbal aggression were controlled for in subsequent analyses. HCP and control subjects did not differ in years of formal education. Control subjects had superior verbal IQ scores, which were about 10 points higher than in subjects with HCP ($P = 0.058$). There were no differences between groups in performance IQ (PIQ) or symptom ratings, except for 'contendedness' (5.8 ± 0.7 vs 5.0 ± 1.1 ; $F = 7.13$, $df = 1, 42$, $P = 0.01$), which is a wellness item indicating freedom from depression and ability to experience happiness, joy and satisfaction. One subject in the HCP group met criteria for lifetime history of ADHD, none met criteria for conduct disorder.

The most prominent finding was a significant reduction in GMV in the right medial frontal gyrus (medial prefrontal cortex, MPFC) in individuals exposed to CP (BA 10; Talairach's coordinates $x = 14$, $y = 47$, $z = 1$, cluster size = 402, $P = 0.037$, corrected cluster level) (Fig. 1). A 19.1% lower average GMV was found in these regions of the CP subjects than in healthy controls.

Using lower criteria for statistical significance revealed 14.5% reduction in GMV in the left medial frontal gyrus (dorsolateral prefrontal cortex; DLPFC) (BA 9; Talairach's coordinates $x = 10$, $y = 40$, $z = 20$, cluster size = 283, $P = 0.015$, uncorrected cluster level) and 16.9% reduction in GMV in the right anterior cingulate gyrus (BA 24; Talairach's coordinates $x = 10$, $y = 30$, $z = 15$, cluster size = 124, $P < 0.001$, uncorrected voxel level). No other areas of reduction were found with a corrected cluster probability value that approached significance.

No significant correlations emerged between the GMV in those regions and symptom ratings (all $P > 0.10$). However, multiple regression analysis revealed that GMV in these identified regions was significantly correlated with PIQ on the WAIS-III (Table II). Overall, there was a 0.634 correlation between GMV and covariates of interest and PIQ for the entire group of subjects ($n = 45$). There was also a significant correlation within the HCP ($r = 0.754$) group alone. As indicated in Table II, there were strong reciprocal correlations between GMV in right BA 10 region and left BA 9 and PIQ. Overall, there was a direct correlation between GMV in left BA 9, and an inverse correlation between right BA 10, and PIQ.

DISCUSSION

This study examined the association between exposure to HCP and brain structure. HCP includes occasional use of objects to induce pain, and is considered an unacceptable form of punishment by the AAP. Results from this study apply to HCP, they do not apply to exposure to ordinary forms of CP that the AAP considers acceptable (but less effective than alternative forms of discipline).

Chronic exposure to HCP was associated with a marked reduction in GMV in the right medial frontal gyrus (MPFC, BA 10). There were also possible associations between HCP and reduced GMV in left medial frontal gyrus (DLPFC, BA 9) and the right anterior cingulate gyrus (BA 24). Other imaging studies have found those regions to be involved in aspects of addiction (Crockford et al., 2005; Drexler et al., 2000), suicidal behavior and/or depression (Bar et al.,

2007; Liotti and Mayberg, 2001; Raust et al., 2007), post-traumatic stress disorder (PTSD) (Bremner, 2003; Fennema-Notestine et al., 2002; Geuze et al., 2007; Hou et al., 2007; Liberzon et al., 2003), dissociative disorders (Veltman et al., 2005), and depression (Fitzgerald et al., 2008). HCP may be an aversive and stressful event for human beings that potentially alters the developmental trajectory of some brain regions in which abnormalities have been associated with major forms of psychopathology.

The regions identified with reduced GMV are part of the medial rostral prefrontal cortex (MRPFC). Recent studies have pointed to the MRPFC as a region of the human brain that plays a crucial role in social cognition as well as functional organization (Amodio and Frith, 2006; Gilbert et al., 2007). In particular, medial BA10 and BA32 appear to be involved with *self-knowledge, person perception and mentalizing* (Amodio and Frith, 2006). At its most basic level, *self-knowledge* involves the ability to differentiate the self from other objects and to recognize attributes and preferences related to oneself. The ability to represent another person's psychological perspective is referred to as *mentalizing*, and this capacity allows us to predict the behavior of others. *Person perception* involves judgments about the attributes and behaviors of others. BA24, in contrast appears to be involved in the internal monitoring of our actions to ensure that they are consistent with intentions and the current situational context (Amodio and Frith, 2006). The more posterior portion of the MRPFC (primarily BA 8 and 9) is activated by cognitive tasks, such as those designed to engage action monitoring and attention. For example, left BA9 is activated in young adults during working memory retrieval tasks (Sun et al., 2005).

It is interesting that individuals exposed to high levels of HCP had reduced GMV in right BA10 and possibly in right BA24. HCP is administered ostensibly to correct behavior. Children may increase their risk of exposure to CP, or HCP, if they have an inadequate ability to internally monitoring their own actions (BA24), or if they have deficits in self-perception, person perception, or mentalizing (BA10). Being able to predict how parents will react, and being able infer their parents' state of mind is probably quite adaptive. Hence, it is conceivable that differences observed in regional GMV were preexisting abnormalities that increased their risk of exposure to HCP. However, exposure to CP began at about 3.9 years of age, when prefrontal cortex is quite immature. BA10 has a particularly protracted pattern of dendritic development (Travis et al., 2005), and medial prefrontal cortex and other components of the 'social brain' undergo structural development, including synaptic reorganization, during adolescence (Blakemore, 2008). Nevertheless, this region of the brain is not quiescent during early development, as episodic memory and episodic future thinking (which requires involvement of medial prefrontal cortex) emerges at about 4 years of age (Weiler and Daum, 2008). It is perhaps most reasonable to assume that the use of CP or HCP for disciplining of young children is strongly dictated by parental experience and beliefs. However, continuing development of MRPFC regions may make it easier for a child to avoid exposure to physical punishment. An inherited lag in the development of the MRPFC may lead to the intergeneration transmission of HCP.

Conversely, exposure to HCP may have attenuated development of these regions. It is conceivable that exposure to HCP produced conflicts in perception and self-monitoring that were difficult to reconcile, and these conflicts attenuated or suppressed development. For example, it may be challenging to integrate perceptions of a parental figure as caring and loving on one hand, and critical and intentionally hurtful on the other. Similarly, there may be a disconnect between a child's self-monitored impression that he did not do much if anything wrong, versus a parental judgment that he needed to be severely punished for his mistakes. In short, HCP may create a mismatch between internal and external perceptions of one's actions or one's beliefs about others. In doing so, it may attenuate or arrest important components of social cognition.

It is interesting that left BA9 GMV was positively correlated with PIQ, while right BA10 was negatively correlated. GMV in BA9 and BA10 were found in a previous study to be two cortical regions most strongly associated with general intelligence (Haier et al., 2005). However, there were substantial gender differences in that study, with BA9 showing a greater correlation in males, and BA10 correlating more significantly in females. As seen in Table II, gender did not significantly affect associations in the present study. The observation that GMV in right BA10 was negatively correlated with PIQ was confusing, but understandable, as IQ may relate even more strongly to white matter volume (or gray/white matter ratio) in BA10 than to GMV alone (Haier et al., 2005).

VBM studies provided an unbiased, even-handed, assessment of regional alterations in GMV. However, these studies have a significant number of limitations. Care was taken to make sure that there were no issues with alignment. Subjects in the two groups were of almost identical age, and selected from a narrow age range to minimize any potential developmental differences in template registration. All subjects were scanned on the same machine over the same time-period. Unfortunately, there were significant differences between groups in gender ratio, parental education level and perceived financial stress, which can independently affect brain development. These factors were controlled for statistically, but these findings will need to be confirmed in samples that are better matched for gender and sociodemographic variables. Our primary concern in this study was to equate the two groups for degree of drug and alcohol use. Although no subject in the study had a history of drug or alcohol abuse, we found that subjects exposed to HCP used these substances to a much greater extent than controls recruited for other studies. The primary finding of reduced GMV in right MPFC was observed with corrected $P < 0.05$. Additional findings of reduced GMV in left DLPFC and right ACC were found to be highly significant at the uncorrected cluster level. There is no guarantee that these were not false-positive results or that all relevant brain areas were identified.

One potential confounding factor is that children with ADHD may have an increased degree of exposure to CP or HCP, though recent studies do not support this association in the USA {Burke, 2008 #5973; Whitmore, 1993 #5972}. Excluding the one child with ADHD in the study did not alter the results. ANCOVA analyses confirmed that there were marked differences in GMV in the three identified regions between HCP subjects and controls when the HCP subject with ADHD was excluded (BA 10: $F_{1,37} = 77.277$ $p < 10^{-9}$; DLPFC: $F_{1,37} = 61.409$ $p < 10^{-8}$; ACC: $F_{1,37} = 49.825$ $p < 10^{-7}$).

Neurobiological research on the effects of early stress has the potential to recast our thinking about the role of early experience in the development of psychopathology (e.g. (Teicher et al., 2002; Teicher et al., 2003)). HCP or excessive CP have been found to be associated with emergence of depression, addiction and aggressive behaviors (Ambati et al., 1998; Banks, 2002; Deater-Deckard et al., 2003; Gershoff, 2002; Lau et al., 2005; Muller et al., 1995; Ohene et al., 2006; Schwartz et al., 2006; Slade and Wissow, 2004; Straus and Kantor, 1994; Straus et al., 1997). These associations may be viewed in a new light, if it turns out to be true that HCP attenuates the development of brain regions crucial for self-knowledge, person perception, mentalizing, and internal monitoring of our actions. Results from this study raise the possibility that exposure to HCP acts as a chronic sub-traumatic stressor that alters the developmental trajectory of MPFC. If so, it underscores efforts to prevent children from receiving CP or HCP from parents or other adults. It should be emphasized that CP received by these subjects was excessive. It involved more than open hand slaps to the buttocks, and in all cases persisted past their 6th birthday. How detrimental (or beneficial) spanking is depends a great deal on the age of the subject, frequency of administration, race, who administers the spanking, family context, and whether it is used as a primary means of discipline, or as a 'backup' strategy (Gunnloe and Mariner, 1997; Larzelere, 1996; Larzelere and Kuhn, 2005). These findings do not necessarily generalize to milder, less frequent, and less persistent

episodes of spanking ending before age 6. Further, we must emphasize again the possibility that reduced GMV in the identified regions may have been a risk factor for persistence (or escalation) of CP, rather than a consequence of exposure. Prospective longitudinal studies will be required to validate and untangle the nature of the relationship.

Acknowledgments

This study was supported by RO1 awards from the U.S.A. National Institute of Mental Health (MH-53636, MH-66222) and National Institute of Drug Abuse (DA-016934, DA-017846) to MHT. We thank Dr. H. Tanabe, National Institute for Physiological Sciences, Aichi, Japan for his assistance with data analyses.

References

- Ambati BK, Ambati J, Rao AM. Corporal punishment and antisocial behavior. *Arch Pediatr Adolesc Med* 1998;152:303. author reply 306–309. [PubMed: 9529474]
- Amodio DM, Frith CD. Meeting of minds: the medial frontal cortex and social cognition. *Nat Rev Neurosci* 2006;7:268–277. [PubMed: 16552413]
- Andersen SL, Tomada A, Vincow ES, Valente E, Polcari A, Teicher MH. Preliminary evidence for sensitive periods in the effect of childhood sexual abuse on regional brain development. *J Neuropsychiatry Clin Neurosci* 2008;20:292–301. [PubMed: 18806232]
- Anderson CM, Teicher MH, Polcari A, Renshaw PF. Abnormal T2 relaxation time in the cerebellar vermis of adults sexually abused in childhood: potential role of the vermis in stress-enhanced risk for drug abuse. *Psychoneuroendocrinology* 2002;27:231–244. [PubMed: 11750781]
- Banks JB. Childhood discipline: challenges for clinicians and parents. *Am Fam Physician* 2002;66:1447–1452. [PubMed: 12408419]
- Bar KJ, Wagner G, Koschke M, Boettger S, Boettger MK, Schlosser R, Sauer H. Increased Prefrontal Activation During Pain Perception in Major Depression. *Biol Psychiatry* 2007;62(11):1281–1287. [PubMed: 17570347]
- Bernstein EM, Putnam FW. Development, reliability and validity of a dissociation scale. *J Nerv Ment Dis* 1986;174:727–735. [PubMed: 3783140]
- Blakemore SJ. The social brain in adolescence. *Nat Rev Neurosci* 2008;9:267–277. [PubMed: 18354399]
- Bremner JD. Long-term effects of childhood abuse on brain and neurobiology. *Child Adolesc Psychiatr Clin N Am* 2003;12:271–292. [PubMed: 12725012]
- Bremner JD, Randall P, Vermetten E, Staib L, Bronen RA, Mazure C, Capelli S, McCarthy G, Innis RB, Charney DS. Magnetic resonance imaging-based measurement of hippocampal volume in posttraumatic stress disorder related to childhood physical and sexual abuse--a preliminary report. *Biol Psychiatry* 1997;41:23–32. [PubMed: 8988792]
- Bugental DB, Martorell GA, Barraza V. The hormonal costs of subtle forms of infant maltreatment. *Horm Behav* 2003;43:237–244. [PubMed: 12614655]
- Choi J, Jeong B, Rohan ML, Polcari AM, Teicher MH. Preliminary Evidence for White Matter Tract Abnormalities in Young Adults Exposed to Parental Verbal Abuse. *Biol Psychiatry*. 2008
- Crockford DN, Goodyear B, Edwards J, Quickfall J, el-Guebaly N. Cue-induced brain activity in pathological gamblers. *Biol Psychiatry* 2005;58:787–795. [PubMed: 15993856]
- De Bellis MD, Keshavan MS, Clark DB, Casey BJ, Giedd JN, Boring AM, Frustaci K, Ryan ND. Developmental traumatology. Part II: Brain development. *Biol Psychiatry* 1999;45:1271–1284. [PubMed: 10349033]
- De Bellis MD, Keshavan MS, Shifflett H, Iyengar S, Beers SR, Hall J, Moritz G. Brain structures in pediatric maltreatment-related posttraumatic stress disorder: a sociodemographically matched study. *Biol Psychiatry* 2002;52:1066–1078. [PubMed: 12460690]
- De Bellis MD, Kuchibhatla M. Cerebellar volumes in pediatric maltreatment-related posttraumatic stress disorder. *Biol Psychiatry* 2006;60:697–703. [PubMed: 16934769]
- Deater-Deckard K, Lansford JE, Dodge KA, Pettit GS, Bates JE. The development of attitudes about physical punishment: an 8-year longitudinal study. *J Fam Psychol* 2003;17:351–360. [PubMed: 14562459]

- Drexler K, Schweitzer JB, Quinn CK, Gross R, Ely TD, Muhammad F, Kilts CD. Neural activity related to anger in cocaine-dependent men: a possible link to violence and relapse. *Am J Addict* 2000;9:331–339. [PubMed: 11155786]
- Fennema-Notestine C, Stein MB, Kennedy CM, Archibald SL, Jernigan TL. Brain morphometry in female victims of intimate partner violence with and without posttraumatic stress disorder. *Biol Psychiatry* 2002;52:1089–1101. [PubMed: 12460692]
- First, MB.; Spitzer, RL.; Gibbon, M.; Williams, JBW. Structured clinical interview for DSM-IV axis I disorders - clinician version (SCID-CV). Washington, DC: American Psychiatric Press; 1997.
- Fitzgerald PB, Laird AR, Maller J, Daskalakis ZJ. A meta-analytic study of changes in brain activation in depression. *Hum Brain Mapp* 2008;29:683–695. [PubMed: 17598168]
- Gershoff ET. Corporal punishment by parents and associated child behaviors and experiences: a meta-analytic and theoretical review. *Psychol Bull* 2002;128:539–579. [PubMed: 12081081]
- Geuze E, Westenberg HG, Jochims A, de Kloet CS, Bohus M, Vermetten E, Schmahl C. Altered pain processing in veterans with posttraumatic stress disorder. *Arch Gen Psychiatry* 2007;64:76–85. [PubMed: 17199057]
- Gilbert SJ, Williamson ID, Dumontheil I, Simons JS, Frith CD, Burgess PW. Distinct regions of medial rostral prefrontal cortex supporting social and nonsocial functions. *Soc Cogn Affect Neurosci* 2007;2:217–226. [PubMed: 18985143]
- Golden CJ, White L, Combs T, Morgan M, McLane D. WMS-R and MAS correlations in a neuropsychological population. *Arch Clin Neuropsychol* 1999;14:265–271. [PubMed: 14590595]
- Good CD, Johnsrude I, Ashburner J, Henson RN, Friston KJ, Frackowiak RS. Cerebral asymmetry and the effects of sex and handedness on brain structure: a voxel-based morphometric analysis of 465 normal adult human brains. *Neuroimage* 2001a;14:685–700. [PubMed: 11506541]
- Good CD, Johnsrude IS, Ashburner J, Henson RN, Friston KJ, Frackowiak RS. A voxel-based morphometric study of ageing in 465 normal adult human brains. *Neuroimage* 2001b;14:21–36. [PubMed: 11525331]
- Gunnoe ML, Mariner CL. Toward a developmental-contextual model of the effects of parental spanking on children's aggression. *Arch Pediatr Adolesc Med* 1997;151:768–775. [PubMed: 9265877]
- Haier RJ, Jung RE, Yeo RA, Head K, Alkire MT. The neuroanatomy of general intelligence: sex matters. *Neuroimage* 2005;25:320–327. [PubMed: 15734366]
- Herman, JL.; Perry, JC.; van der Kolk, BA. Traumatic Antecedents Interview. The Trauma Center; Boston: 1989.
- Hou C, Liu J, Wang K, Li L, Liang M, He Z, Liu Y, Zhang Y, Li W, Jiang T. Brain responses to symptom provocation and trauma-related short-term memory recall in coal mining accident survivors with acute severe PTSD. *Brain Res* 2007;1144:165–174. [PubMed: 17331476]
- Kellner R. A symptom questionnaire. *Journal of Clinical Psychiatry* 1987;48:268–273. [PubMed: 3597327]
- Larzelere RE. A review of the outcomes of parental use of nonabusive or customary physical punishment. *Pediatrics* 1996;98:824–828. [PubMed: 8885980]
- Larzelere RE, Kuhn BR. Comparing child outcomes of physical punishment and alternative disciplinary tactics: a meta-analysis. *Clin Child Fam Psychol Rev* 2005;8:1–37. [PubMed: 15898303]
- Lau JT, Kim JH, Tsui HY, Cheung A, Lau M, Yu A. The relationship between physical maltreatment and substance use among adolescents: a survey of 95,788 adolescents in Hong Kong. *J Adolesc Health* 2005;37:110–119. [PubMed: 16026720]
- Liberzon I, Britton JC, Phan KL. Neural correlates of traumatic recall in posttraumatic stress disorder. *Stress* 2003;6:151–156. [PubMed: 13129808]
- Liotti M, Mayberg HS. The role of functional neuroimaging in the neuropsychology of depression. *J Clin Exp Neuropsychol* 2001;23:121–136. [PubMed: 11320448]
- Medina AM, Mejia VY, Schell AM, Dawson ME, Margolin G. Startle reactivity and PTSD symptoms in a community sample of women. *Psychiatry Res* 2001;101:157–169. [PubMed: 11286819]
- Muller RT, Hunter JE, Stollak G. The intergenerational transmission of corporal punishment: a comparison of social learning and temperament models. *Child Abuse Negl* 1995;19:1323–1335. [PubMed: 8591089]

- Ohene SA, Ireland M, McNeely C, Borowsky IW. Parental expectations, physical punishment, and violence among adolescents who score positive on a psychosocial screening test in primary care. *Pediatrics* 2006;117:441–447. [PubMed: 16452364]
- Raust A, Slama F, Mathieu F, Roy I, Chenu A, Koncke D, Fouques D, Jollant F, Jouvent E, Courtet P, Leboyer M, Bellivier F. Prefrontal cortex dysfunction in patients with suicidal behavior. *Psychol Med* 2007;37:411–419. [PubMed: 17049103]
- Richert KA, Carrion VG, Karchemskiy A, Reiss AL. Regional differences of the prefrontal cortex in pediatric PTSD: an MRI study. *Depress Anxiety* 2006;23:17–25. [PubMed: 16247760]
- Schwartz JP, Hage SM, Bush I, Burns LK. Unhealthy parenting and potential mediators as contributing factors to future intimate violence: a review of the literature. *Trauma Violence Abuse* 2006;7:206–221. [PubMed: 16785287]
- Slade EP, Wissow LS. Spanking in early childhood and later behavior problems: a prospective study of infants and young toddlers. *Pediatrics* 2004;113:1321–1330. [PubMed: 15121948]
- Straus MA, Kantor GK. Corporal punishment of adolescents by parents: a risk factor in the epidemiology of depression, suicide, alcohol abuse, child abuse, and wife beating. *Adolescence* 1994;29:543–561. [PubMed: 7832020]
- Straus MA, Sugarman DB, Giles-Sims J. Spanking by parents and subsequent antisocial behavior of children. *Arch Pediatr Adolesc Med* 1997;151:761–767. [PubMed: 9265876]
- Sun X, Zhang X, Chen X, Zhang P, Bao M, Zhang D, Chen J, He S, Hu X. Age-dependent brain activation during forward and backward digit recall revealed by fMRI. *Neuroimage* 2005;26:36–47. [PubMed: 15862203]
- Teicher MH, Andersen SL, Polcari A, Anderson CM, Navalta CP. Developmental neurobiology of childhood stress and trauma. *Psychiatr Clin North Am* 2002;25:397–426. [PubMed: 12136507]
- Teicher MH, Andersen SL, Polcari A, Anderson CM, Navalta CP, Kim DM. The neurobiological consequences of early stress and childhood maltreatment. *Neurosci Biobehav Rev* 2003;27:33–44. [PubMed: 12732221]
- Teicher MH, Dumont NL, Ito Y, Vaituzis C, Giedd JN, Andersen SL. Childhood neglect is associated with reduced corpus callosum area. *Biol Psychiatry* 2004;56:80–85. [PubMed: 15231439]
- Teicher MH, Glod CA, Surrey J, Swett C Jr. Early childhood abuse and limbic system ratings in adult psychiatric outpatients. *Journal of Neuropsychiatry & Clinical Neurosciences* 1993;5:301–306. [PubMed: 8369640]
- Teicher, MH.; Ito, Y.; Glod, CA.; Andersen, SL., et al. Preliminary evidence for abnormal cortical development in physically and sexually abused children using EEG coherence and MRI. In: Yehuda, R.; McFarlane, AC., et al., editors. *Psychobiology of posttraumatic stress disorder*. New York academy of science; New York: 1997. p. 160-175.
- Teicher MH, Samson JA, Polcari A, McGrenery CE. Sticks, stones, and hurtful words: relative effects of various forms of childhood maltreatment. *Am J Psychiatry* 2006;163:993–1000. [PubMed: 16741199]
- Travis K, Ford K, Jacobs B. Regional dendritic variation in neonatal human cortex: a quantitative Golgi study. *Dev Neurosci* 2005;27:277–287. [PubMed: 16137985]
- Veltman DJ, de Ruiter MB, Rombouts SA, Lazeron RH, Barkhof F, Van Dyck R, Dolan RJ, Phaf RH. Neurophysiological correlates of increased verbal working memory in high-dissociative participants: a functional MRI study. *Psychol Med* 2005;35:175–185. [PubMed: 15841675]
- Wechsler, D. *Wechsler Adult Intelligence Scale-III Administration and Scoring Manual*. The Psychological Corporation; San Antonio: TX: 1997.
- Weiler JA, Daum I. [Mental time travel - the neurocognitive basis of future thinking]. *Fortschr Neurol Psychiatr* 2008;76:539–548. [PubMed: 18712666]

Fig. 1. Significant differences between corporal punishment (CP) subjects and controls. Significantly lower gray-matter densities in CP subjects were measured in the right medial frontal gyrus (medial prefrontal cortex, BA10). Crosshairs placed at $x=14$, $y=47$, $z=1$, the right medial prefrontal cortex. Color scale: 0–5 represent t -values.

Table I

Demographics and subject characteristics for VBM Comparisons

Measures	Healthy Controls	Harsh Corporal Punishment	ANOVA F-value	p-value
Subjects	22	23		
Male/Female	6M/16F	15M/8F	Fisher Exact	0.017
Age	21.68±1.84	21.74±2.22	0.009	0.925
Parental Education (yrs)	16.48±2.24	14.39±2.37	9.179	0.004
Financial Sufficiency	3.64±0.66	3.09±0.73	6.977	0.01
Parental Verbal Aggression	11.23±5.82	23.2±11.64	18.773	<0.0001
Education (yrs) ^a	13.89±1.60	14.23±1.53	0.965	0.323
Verbal IQ ^b	127.6±14.7	117.7±14.9	3.821	0.058
Performance IQ ^b	118.7±10.2	119.5±12.6	0.041	0.841

^a ANCOVA with age and gender as covariates^b ANCOVA with gender as covariate

Multiple regression analysis between prefrontal cortex gray matter volume and performance IQ scores.

Table II

Independent Variables	All Subjects		HCP Only		Controls Only	
	Beta	P-value	Beta	P-value	Beta	P-value
Right Medial PFC (BA 10)	-1.89	<0.001	-1.386	0.007	-2.054	0.026
Left dorsolateral PFC (BA 9)	1.745	0.002	1.277	0.018	0.779	NS
Right Anterior Cingulate (BA 24)	0.307	NS	0.453	NS	1.261	NS
Gender	0.03	NS	-0.023	NS	0.005	NS
Parental education	0.054	NS	-0.245	NS	0.227	NS
Financial sufficiency	-0.113	NS	0.262	NS	-0.507	NS
r value	0.634	0.006	0.752	0.04	0.65	NS