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Reduced orbitofrontal and temporal grey matter in a community sample of maltreated children

Stéphane A. De Brito, Essi Viding, Catherine L. Sebastian, Philip A. Kelly, Andrea Mechelli, Helen Maris, and Eamon J. McCrory

Division of Psychology and Language Sciences, University College London, London, UK; The Anna Freud Centre, London, UK; Institute of Cognitive Neuroscience, University College London, London, UK; Department of Psychosis Studies, Institute of Psychiatry, King’s College London, London, UK

Background: Childhood maltreatment is strongly associated with increased risk of psychiatric disorder. Previous neuroimaging studies have reported atypical neural structure in the orbitofrontal cortex, temporal lobe, amygdala, hippocampus and cerebellum in maltreated samples. It has been hypothesised that these structural differences may relate to increased psychiatric vulnerability. However, previous studies have typically recruited clinical samples with concurrent psychiatric disorders, or have poorly characterised the range of maltreatment experiences and levels of concurrent anxiety or depression, limiting the interpretation of the observed structural differences. Methods: We used voxel-based morphometry to compare grey matter volume in a group of 18 children (mean age 12.01 years, SD = 1.4), referred to community social services, with documented and well-characterised experiences of maltreatment at home and a group of 20 nonmaltreated children (mean age 12.6 years, SD = 1.3). Both groups were comparable on age, gender, cognitive ability, ethnicity and levels of anxiety, depression and posttraumatic stress symptoms. We examined five a priori regions of interest: the prefrontal cortex, temporal lobes, amygdala, hippocampus and cerebellum. Results: Maltreated children, compared to nonmaltreated peers, presented with reduced grey matter in the medial orbitofrontal cortex and the left middle temporal gyrus. Conclusions: The medial orbitofrontal cortex and the middle temporal gyrus have been implicated in reinforcement-based decision-making, emotion regulation and autobiographical memory, processes that are impaired in a number of psychiatric disorders associated with maltreatment. We speculate that grey matter disturbance in these regions in a community sample of maltreated children may represent a latent neurobiological risk factor for later psychopathology and heightened risk taking. Keywords: maltreatment, child abuse, orbitofrontal cortex, middle temporal gyrus, voxel-based morphometry.

Introduction

Childhood maltreatment, including neglect, physical, sexual and emotional abuse, remains a major public-health concern (Gilbert et al., 2009). Exposure to maltreatment has been consistently associated with poor outcome in relation to physical health, social and academic functioning, economic productivity (Gilbert et al., 2009) and increased risk of a range of psychiatric disorders (e.g. Scott, McLaughlin, Smith, & Ellis, 2012). While many of these associations have been well replicated, there is limited understanding of the neural changes associated with maltreatment exposure, which may heighten developmental vulnerability to these outcomes.

Animal studies have established a causal relationship between early stressful care-giving experiences, increased volume of the amygdala, decreased volume of the hippocampus, prefrontal cortex and corpus callosum (Arnsten, 2009; Hill, Hillard, & McEwen, 2011; Jackowski et al., 2011). Crucially, early stressful care-giving experiences have been shown to be causally related to deficits in social, affective and cognitive functioning, comparable to those seen in psychiatric conditions, such as depression and anxiety disorders (Sánchez, Ladd, & Plotsky, 2001).

Studies of humans have employed structural magnetic resonance imaging (sMRI) to investigate in vivo the neural correlates of maltreatment in both adults with childhood histories of maltreatment and children who have experienced maltreatment or institutionalisation (McCrory, De Brito, & Viding, 2011). Consistent with findings from the animal literature adult studies have reported consistent patterns of reduced hippocampal and prefrontal cortex volumes; however, these findings have generally been obtained in samples presenting with posttraumatic stress disorder (PTSD) or depression (McCrory et al., 2011; but see Dannlowski et al., 2012; Teicher, Anderson, & Polcari, 2012). Most previous studies have found no difference in amygdala volume or in the temporal lobe more generally (see McCrory et al., 2011 for a review), a somewhat surprising pattern in...
light of the animal literature (but see Vermetten, Schmahl, Lindner, Loewenstein, & Bremner, 2006; Tomoda et al., 2011).

From a developmental perspective, the interpretation of adult sMRI studies is problematic, as in most cases, many years have passed since maltreatment exposure. Indeed, structural brain differences observed in adulthood may reflect brain reorganisation in response to early stress, the impact of a new environmental risk associated with maltreatment (such as alcohol abuse), or alterations in brain structure associated with concurrent psychiatric disorders. By studying nonclinically referred samples of children in the community who have experienced maltreatment, we can begin to delineate those neural correlates primarily associated with maltreatment that may underpin future psychiatric vulnerability.

Consistent with the adult literature, differences have not generally been observed in amygdala volume in maltreated children with PTSD (Woon & Hedges, 2008). However, two recent studies have reported increased amygdala volume in children who have experienced institutional deprivation in infancy (Mehta et al., 2009; Tottenham et al., 2010), suggesting that amygdala volume may be influenced only by early and severe adversity (Tottenham & Sheridan, 2010). There are mixed findings in relation to the temporal lobe more generally (De Bellis, Hall, Boring, Frustaci, & Moritz, 2001; De Bellis et al., 2002; Hanson et al., 2010).

There are three notable differences between studies of children and adults with histories of maltreatment and PTSD. First, the hippocampus typically shows reduced volume in adult samples, but appears to be of normal volume in child samples (McCrorry et al., 2011). Second, the cerebellum typically shows reduced volume in maltreated children, but not in adult samples (Bauer, Hanson, Pierson, Davidson, & Pollak, 2009; Carrion et al., 2009; De Bellis & Kuchibhatla, 2006). Finally, whereas for adult samples, there is a consistent pattern of reduced grey matter volume in the prefrontal cortex, the pattern of findings for maltreated children has been mixed (Carrion, Weems, Richert, Hoffman, & Reiss, 2010; Carrion et al., 2009; De Bellis et al., 1999; Hanson et al., 2010).

A general limitation of most previous structural imaging studies examining grey matter in children exposed to maltreatment at home is that they have mainly recruited clinical samples with concurrent psychiatric diagnoses such as PTSD; however, only a proportion of children exposed to maltreatment will develop a psychiatric disorder in childhood (DuMont, Widom, & Czaja, 2007). Studying a community sample of children, free from clinical levels of PTSD, anxiety and depression symptoms, would reduce the likelihood that any observed structural differences are associated with internalising problems. However, the possibility that other undetected psychiatric difficulties may contribute to observed structural differences in maltreated children cannot, of course, be discounted. One exception is a recent study by Hanson and colleagues, who recruited a community sample of physically maltreated children (Hanson et al., 2010). Using tensor-based morphometry, they found reduced grey matter volume in the orbitofrontal cortex (OFC) and in the middle temporal lobe. However, this study was limited in a number of respects. No dimensional indices of anxiety or depression were provided even though several of the maltreated children had psychiatric diagnoses. Similarly, the maltreatment experiences of the children were not fully characterised – only the presence of physical abuse was reported. Finally, IQ was not assessed. These limitations make it difficult to be confident that the observed structural differences can be generalised to the kinds of children typically referred to social services who present with more than one type of maltreatment experience (Dong et al., 2004). It is also possible that elevated, but subclinical levels of anxiety and depression (or differences in general cognitive ability) characterised the maltreated group, and contributed to the observed structural differences.

In the present study, we used voxel-based morphometry (VBM), a whole brain, automated and unbiased technique (Ashburner & Friston, 2000), to compare grey matter volume of healthy children exposed to documented maltreatment at home to that of a group of nonmaltreated peers comparable on sex, age, self-reported Tanner stage, handedness, cognitive ability, ethnicity and concurrent levels of internalising psychopathology including anxiety, depression and posttraumatic stress symptoms. We also detailed the range of maltreatment each child experienced to ensure that our sample was representative of cases commonly seen by clinical and social services. We identified five regions of interest (ROIs): the prefrontal cortex (Carrion et al., 2010; Hanson et al., 2010), temporal lobes (De Bellis et al., 2002; Hanson et al., 2010), amygdala (Mehta et al., 2009; Tottenham et al., 2010), hippocampus (Woon & Hedges, 2008) and cerebellum (Bauer et al., 2009; Carrion et al., 2009; De Bellis & Kuchibhatla, 2006). Given the general pattern of findings in the literature, we hypothesised that maltreated children, compared with their nonmaltreated peers, would exhibit decreased grey matter in the prefrontal cortex, temporal lobe and cerebellum. No differences were expected in amygdala and hippocampal volumes.

Methods and materials

Participants

Children (male and female) aged 10–14 years were recruited from the London area for this study (Table 1). The Supplementary Information provides
details of all recruited children, including those who were subsequently excluded. The final sample comprised two groups: children with documented exposure to maltreatment at home (Maltreated group, \( n = 18 \)); and children free from maltreatment experience (Nonmaltreated children, \( n = 20 \)). The maltreated group were recruited via a community Social Services department (SS) and were competent to consent, in a stable home placement and not learning disabled. Informed assent was obtained from the child and consent from a parent. Where there was shared parental responsibility, consent was obtained from the child’s biological parent if contactable, and from SS. Nonmaltreated children, similar in terms of sex, age, self-reported Tanner stage, handedness, cognitive ability and ethnicity were recruited from local primary/secondary schools and via advertisement in local newspapers and on the Internet. Exclusion criteria included a history of abuse, neglect and exposure to intimate-partner violence as reported by the main carer on the Child Bad Experience Questionnaire (Dodge, Bates, & Pettit, 1990) and the Dunedin Abuse Scales (Magdol, Moffitt, Caspi, & Silva, 1998) and previous contact with SS regarding the child’s care. Informed assent and consent were obtained from the child and their parent(s) respectively.

All participants completed a comprehensive battery of psychological measures (see Measures section below and Table 1). None of the participants reported a history of head trauma, neurological disease, foetal alcohol syndrome, a psychiatric diagnosis or contraindications for MRI. The study was approved by University College London Ethics Committee (0895/002).

### Measures

**Maltreatment history** SS case files for the maltreated group were independently rated by the child’s social worker in relation to neglect (\( n = 16 \); described below).

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**Table 1** Background characteristics and questionnaire data for nonmaltreated and maltreated children

<table>
<thead>
<tr>
<th></th>
<th>Nonmaltreated (( n = 20 ))</th>
<th>Maltreated (( n = 18 ))</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, no. of males (%)</td>
<td>10 (50)</td>
<td>11 (61)</td>
<td>.53</td>
</tr>
<tr>
<td>Ethnicity, no. of Caucasian (%)</td>
<td>9 (45)</td>
<td>7 (39)</td>
<td>.75</td>
</tr>
<tr>
<td>Tanner stage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of pre/early pubertal (%)</td>
<td>6 (30)</td>
<td>6 (33)</td>
<td>1</td>
</tr>
<tr>
<td>No. of mid/late pubertal (%)</td>
<td>14 (70)</td>
<td>12 (67)</td>
<td>1</td>
</tr>
<tr>
<td>Handedness</td>
<td>1 left, 18 right, 1 ambidextrous</td>
<td>15 right, 3 unknown</td>
<td>.16</td>
</tr>
<tr>
<td>Age (in years)</td>
<td>12.63</td>
<td>12.01</td>
<td>.16</td>
</tr>
<tr>
<td>SES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest level of education*</td>
<td>2.95</td>
<td>2.28</td>
<td>.13</td>
</tr>
<tr>
<td>Wechsler abbreviated scale of intelligence</td>
<td>109.2</td>
<td>103.67</td>
<td>.11</td>
</tr>
<tr>
<td>Full scale IQ</td>
<td>10.66</td>
<td>10.31</td>
<td>.11</td>
</tr>
<tr>
<td>Mood and feelings questionnareb</td>
<td>10.95</td>
<td>9.14</td>
<td>0.79</td>
</tr>
<tr>
<td>Total score</td>
<td>7.85</td>
<td>11.71</td>
<td></td>
</tr>
<tr>
<td>Trauma symptom checklist for childrenb</td>
<td>32.1</td>
<td>33.35</td>
<td>0.63</td>
</tr>
<tr>
<td>Anxiety</td>
<td>47.79</td>
<td>47.76</td>
<td>1</td>
</tr>
<tr>
<td>Depression</td>
<td>45.47</td>
<td>54.47</td>
<td>0.96</td>
</tr>
<tr>
<td>Anger</td>
<td>44.42</td>
<td>46.47</td>
<td>0.52</td>
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<tr>
<td>Post-traumatic stress</td>
<td>44.84</td>
<td>49.59</td>
<td>0.14</td>
</tr>
<tr>
<td>Dissociation</td>
<td>47.42</td>
<td>51.12</td>
<td>0.22</td>
</tr>
<tr>
<td>State/trait anxiety inventory for childrenb</td>
<td>32.1</td>
<td>33.35</td>
<td>0.63</td>
</tr>
<tr>
<td>Trait</td>
<td>32.1</td>
<td>33.35</td>
<td>0.63</td>
</tr>
<tr>
<td>State</td>
<td>27.2</td>
<td>25.76</td>
<td>0.27</td>
</tr>
<tr>
<td>Total</td>
<td>59.3</td>
<td>59.88</td>
<td>0.87</td>
</tr>
<tr>
<td>Strength and difficulties questionnarec</td>
<td>1.30</td>
<td>3.50</td>
<td>0.00</td>
</tr>
<tr>
<td>Conduct problems</td>
<td>1.60</td>
<td>1.67</td>
<td>0.90</td>
</tr>
<tr>
<td>Peer problems</td>
<td>2.55</td>
<td>2.50</td>
<td>0.92</td>
</tr>
<tr>
<td>Emotional problems</td>
<td>8.10</td>
<td>8.26</td>
<td>0.81</td>
</tr>
<tr>
<td>Prosocial behaviour</td>
<td>3.25</td>
<td>5.29</td>
<td>0.00</td>
</tr>
</tbody>
</table>

All \( p \)-values derived from t-tests with the exception of the gender, ethnicity and Tanner stage comparisons, which used the Fisher’s exact test. SES, socioeconomic status.

*The highest level of education attained by the mother or long-term foster mother was taken as an indicator of socioeconomic status and evaluated on a scale of 1–5 (1 = No formal qualifications; 5 = Postgraduate Level). These data were available for 17 of the children in the maltreated group.

*Child rated.

*Parent rated.
M = 2.56, SD = 1.21), sexual (n = 5; M = 2.00, SD = 1.87), physical (n = 7; M = 1.57, SD = 0.54) and emotional abuse (n = 16; M = 3.00, SD = 1.07) on Kaufman’s 4-point scale (Kaufman, Jones, Steiglitz, Vitulano, & Mannarino, 1994). Of those emotionally abused, 15 had witnessed intimate-partner violence. Further details regarding age of onset and duration of maltreatment as estimated by the child’s social worker are provided in the Supplementary Information. Five cases in the maltreated group were double-rated by a senior social work professional; there was 80% agreement in relation to the presence of physical abuse and sexual abuse and 100% agreement in relation to the presence of emotional abuse and neglect. Harsh parental physical discipline, defined as the use of harsh corporal punishment to discipline the child for at least 3 years on a monthly basis with occasional use of an object was also rated; nine children had been routinely disciplined in this way.

Child Bad experience questionnaire Main carers were administered a standardised classical interview protocol that includes probe questions on bullying, accidents, harsh discipline, physical and sexual abuse (Dodge et al., 1990).

Intimate-partner violence The Physical Abuse scale from the Dunedin Abuse Scales (Magdol et al., 1998) was used to assess intimate-partner violence in the nonmaltreated group.

Cognitive ability The Vocabulary and Matrix Reasoning subscales of the Wechsler Abbreviated Scales of Intelligence (Wechsler, 1999) were used to provide an estimate of Full Scale Intelligence Quotient (FSIQ).

Socioeconomic status (SES) The highest level of education attained by the mother or long-term foster mother was taken as an indicator of SES and evaluated on a 5-point scale (from 0 = formal qualification, to 5 = postgraduate or professional qualification).

Pubertal status Pubertal development was assessed using the Puberty Development Scale (Petersen, Crockett, Richards, & Boxer, 1988), an eight item self-report measure of physical development based on Tanner stages.

Clinical symptoms of the self-report State-Trait Anxiety Inventory for Children (Spielberger, 1973) was used to assess state and trait anxiety. This measure consists of two separate 20-item scales. The Mood and Feelings Questionnaire (Angold, Costello, & Messer, 1996) a 33-item self-report measure, was used to assesses core depressive symptoms in children. The Trauma Symptom Checklist for Children – A (Briere, 1996), a 44-item self-report measure, was used to assess acute and chronic posttraumatic symptomatology and other symptom clusters. It includes two validity scales and five clinical scales (Anger, Anxiety, Depression, Posttraumatic stress and Dissociation). Finally, The Strength and Difficulties Questionnaire (SDQ; Goodman, 1997), a 25-item measure, was also included to assess general psychological and behavioural functioning as rated by the child’s parent/carer. The SDQ includes five subscales: conduct problems, emotional symptoms, hyperactivity, peer problems and prosocial behaviour scores.

Image acquisition
Participants were scanned on a 1.5 Tesla Siemens (Siemens Medical Systems, Erlander, Germany) Avanto MRI scanner with a 32-channel head coil. A high-resolution, 3D T1-weighted structural scan using a magnetization prepared rapid gradient echo (MPRAGE) sequence was acquired with the following parameters: 176 slices; slice thickness = 1 mm; gap between slices = 0.5 mm; TR = 2730 ms; TE = 3.57 ms; field of view = 256 mm × 256mm²; matrix size = 256 × 256; voxel size = 1 × 1 × 1 mm resolution).

Image processing
Data were processed using the Statistical Parametric Mapping software version 8 (SPM8; Wellcome Department of Imaging Neuroscience, London, UK; http://www.fil.ion.ucl.ac.uk/spm/software/spm8) and the VBM8 Toolbox (http://dbm.neuro.uni-jena.de/vbm8.html), implemented in MATLAB 7.5 (Mathworks, Sherborn, MA). Customised tissue probability maps were created in Montreal Neurological Institute (MNI) space for use with the VBM8 Toolbox. These customised tissue probability maps were produced using the matched template approach of the Template-O-Matic Toolbox for SPM8 (Wilke, Holland, Altaye, & Gaser, 2008) with each participant’s age and gender as defining variables. All T1-weighted images were then corrected for bias-field inhomogeneities, spatially normalised and segmented into grey matter, white matter and cerebrospinal fluid within the same generative model (Ashburner & Friston, 2005). Crucially, the voxel values in the grey matter segments were only multiplied by the nonlinear component of the registration to account for individual differences in brain size. The modulated grey matter segments were written out with an isotropic voxel resolution of 1.5 mm³. Grey matter segments were then smoothed with an 8 × 8 × 8 mm³ full-width at half-maximum Gaussian kernel.

Statistical analyses
Regionally specific between-group differences in grey matter volume were assessed in SPM8 using two-sample t-test models, controlling for age, gender and
FSIQ because of their known associations with brain anatomy (Giedd & Rapoport, 2010). Given our strong a priori hypotheses, we constrained our search to a predefined mask, which consisted of a total of 227,560 voxels. The mask included the following ROIs bilaterally: (a) amygdala, (b) hippocampus, (c) prefrontal cortex, (d) temporal lobe and (e) cerebellum. These ROIs were defined using the automated anatomical labelling as implemented in WFU Pick-atlas toolbox (Maldjian, Laurienti, Kraft, & Burdette, 2003). Inferences within this mask were made using a statistical threshold of \( p < 0.05 \) after Family-Wise Error (FWE) correction for multiple comparisons. When significant effects were detected, grey matter signal was extracted and correlations were conducted with age of onset, duration and severity of each maltreatment subtype and those symptom domains found to be significantly elevated in the maltreated group.

Finally, for completeness, we also explored trends for group differences at whole brain level using a statistical threshold of \( p < 0.001 \), uncorrected (see Supporting Information); however, in the discussion, we focus on those regions that survive correction within our mask.

**Results**

**Demographic and behavioural characteristics**

The maltreated group did not differ from the non-maltreated group in relation to sex, age, self-reported Tanner stage, handedness, FSIQ, SES and ethnicity (Table 1). Although the two groups were similar in terms of their levels of anxiety, depression and PTSD symptoms, the maltreated group showed higher SDQ conduct problem and hyperactivity symptoms.

**Total intracranial volume, overall grey matter, white matter volume, and cerebrospinal fluid**

The maltreated group, in comparison with the non-maltreated group, had lower overall grey matter volume (746.10 ± 54.93 ml vs. 787.10 ml ± 61.77; \( t(36) = 2.15, p = .04 \), but no group differences were observed for white matter volume (464.06 ml ± 37.56 vs. 481.84 ml ± 49.50; \( t(36) = 1.24, p = .22 \)), cerebrospinal fluid (168.23 ml ± 21.37 vs. 164.13 ml ± 24.44; \( t(36) = -.55, p = .59 \)) or total intracranial volume (1,378.39 ml ± 95.87 vs. 1,433.07 ml ± 114.31; \( t(36) = 1.59, p = .12 \)).

**Regions of interest grey matter volume**

The maltreated group, in comparison with the non-maltreated group, exhibited reduced grey matter in the medial OFC (Figure 1(A); MNI coordinates: \( x = -11; y = 26; z = -21; Z\)-score = 5.25; \( p = .005 \) FWE corrected; cluster size = 36) and laterally in the middle temporal gyrus (Figure 1(B); \( x = -60; y = -1; z = -27; Z\)-score = 5.19; \( p = .006 \) FWE corrected; cluster size = 21). These clusters were significant with a whole brain FWE correction (\( p < 0.05 \)) and remained significant when SDQ conduct problems and hyperactivity symptoms were covaried out (see Supporting Information). No significant correlations were found between grey matter volume in the medial OFC, middle temporal gyrus and measures of maltreatment experience or level of conduct problem and hyperactivity symptoms. In the remaining three ROIs – amygdala, hippocampus and cerebellum – no significant group differences in grey matter volume (increase or decrease) were observed, even when the statistical threshold was lowered to \( p < .001 \), uncorrected.

**Discussion**

This study is the first to use VBM to compare grey matter volume in a community sample of maltreated children with a group of carefully matched peers. The maltreated group, compared with nonmaltreated children, exhibited decreased grey matter volume in two regions: the medial OFC and the left lateral middle temporal gyrus. These differences are unlikely to be associated with clinical symptomatology, cognitive ability, or demographic characteristics.

![Figure 1](image-url)
Rather, we suggest that reduced grey matter volume in these regions reflects exposure to maltreatment. Consistent with our predictions, no group differences were detected in the amygdala or hippocampus. However, contrary to our predictions, no group differences were found in relation to cerebellar grey matter volume.

Our finding that a community sample of maltreated children exhibit decreased grey matter volume in the medial OFC is of interest, as this is a region implicated in reinforcement-based decision-making and emotion regulation (Ochsner & Gross, 2005; Schoenbaum, Saddoris, & Stalnaker, 2007). Animal work has demonstrated that early stress leads to structural alterations in this region (Arnsten, 2009). There is also prospective longitudinal evidence that chronic stress in humans is associated with decreased grey matter in the OFC (Gianaros et al., 2007). Maltreatment has been associated with an increased risk of substance misuse, antisocial personality disorder and depression; conditions characterised by decreased grey matter in the OFC (Ersche et al., 2011; Kempton et al., 2011; Narayan et al., 2007). Crucially, these psychiatric disorders have all been associated with disturbance in reinforcement-based decision-making and emotion regulation (e.g., Cella, Dymond, & Cooper, 2010; Davidson, Putnam, & Larson, 2000; Marroquin, 2011). We suggest that the morphological abnormalities within the OFC may contribute to impairments in social functioning and heightened risk-taking behaviour, particularly as these maltreated children enter adolescence (Hanson et al., 2010).

The maltreated group also exhibited reduced grey matter in the middle temporal gyrus. Brain imaging work on nonhuman primates has established a causal relationship between early stress and reduced grey matter in this region (Jackowski et al., 2011). The middle temporal gyrus is implicated in autobiographical memory retrieval (Holland, Addis, & Kensinger, 2011). An over-general autobiographical memory has been shown to characterise a number of psychiatric disorders as associated with decreased grey matter in the OFC (Kuchibhatla, 2006; De Bellis & Kuchibhatla, 2006). Several methodological limitations should be noted. First, we used a cross-sectional design, which limits our ability to make causal inferences between maltreatment experience and grey matter differences. Second, our measures of psychopathology relied on a child's self-report and parent report rather than being based on a formal clinical psychiatric interview. Third, although maltreated children with diagnosed foetal alcohol syndrome were excluded from the study, we cannot completely rule out that some of the observed effects may have been due to prenatal exposure to teratogens. Finally, the double-rating for presence of maltreatment history could only be performed on a subset of cases and ideally dual ratings would have been obtained for all cases. However, this study was also characterised by several strengths. First, we compared a community-referred sample of maltreated children without clinical levels of PTSD, anxiety and depression symptoms with nonmaltreated peers, thereby ensuring that interpretation of group differences were not confounded by the presence of internalising psychopathology. Second, because the potential effects of age, sex and FSIQ were controlled for in our analyses, the observed group differences are unlikely to be due to these factors. Third, by characterising the complex nature of the children's maltreatment experiences, we are confident that our sample is representative of the maltreatment cases typically referred to community social services departments.

In summary, this is the first VBM study to compare a community sample of maltreated children with a group of nonmaltreated well-matched peers. We provide novel evidence that maltreated children with normative levels of internalising psychopathology present with significantly reduced grey matter in two key regions: the medial OFC and the left middle temporal gyrus. Functionally, these regions are implicated in decision-making, emotion regulation and autobiographical memory, processes that are impaired in a number of psychiatric disorders asso-
associated with maltreatment. We suggest that the observed grey matter disturbance may represent a latent neurobiological risk factor for later psychopathology and heightened risk-taking behaviour. Longitudinal studies are required to test this hypothesis directly.

**Supporting information**

Additional Supporting Information may be found in the online version of this article:

**Table S1** Abuse subtype severity, age of onset and duration in years

**Table S2** Whole brain group differences \( p < .001 \) uncorrected with an extent threshold of 35 voxels

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**Correspondence**

Eamon J. McCrory, Division of Psychology and Language Sciences, University College London, 26 Bedford Way, London, WC1H 0AP, UK; E-mail: e.mccrory@ucl.ac.uk

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**Key points**

- Previous neuroimaging studies that have reported atypical neural structure in maltreated children have typically recruited samples with concurrent psychiatric disorders.

- We compared grey matter volume in a community sample of maltreated children and a group of nonmaltreated peers showing similar levels of internalising symptoms.

- Maltreated children exhibited reduced grey matter in the medial OFC and the left middle temporal gyrus.

- Grey matter disturbance in these regions may represent a latent neurobiological risk factor for later psychopathology. In other words, differences in neural structure may increase vulnerability to later stress.

**References**


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