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Neural correlates of face familiarity in institutionalised children and links to attachment disordered behaviour

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Background: One of the most well-documented sequelae of early maltreatment and institutionalisation is attachment problems, including behaviours under the labels of reactive attachment disorder (RAD) and disinhibited social engagement disorder (DSED). Despite growing evidence of the neurobiological effects of institutionalisation, the neural correlates of these behavioural patterns are largely unknown. **Methods:** The current study examined effects of both institutionalisation in general and attachment disordered behaviour, in particular, on brain-based markers of face processing, in 100 Portuguese children (70 currently institutionalised, 30 continuously raised by their families). Children's neural processing of caregiver's and stranger's faces was assessed with Event-Related Potentials (ERPs). **Results:** Compared to children from the community, institutionalised children showed smaller amplitudes in the N170, to both stranger and caregiver faces. Amongst the institutionalised group, living in a setting with a higher children-to-caregivers' ratio was associated with smaller P400 amplitudes. The display of DSED symptoms was associated with a smaller P1 to both faces, as well as a reduced differentiation between faces in P400 amplitudes and smaller P400 to the stranger's face. In contrast, RAD symptoms were not associated with any ERP measures. **Conclusions:** Results replicate previously reported hypoactivation in institutionalised children, in a less-globally deprived setting than past work, indicating that such a pattern is associated with lack of individualised care and increased symptoms of DSED. **Keywords:** Looked-after children; attachment disorders; deprivation; event-related potentials; face processing; reactive attachment disorder; disinhibited social engagement disorder.

Introduction

Early institutionalisation, which generally entails exposure to at least some form of psychosocial neglect, is known to compromise multiple aspects of children's development (van IJzendoorn et al., 2020). Problems include atypical patterns of relating to caregivers and unfamiliar adults, first reported over 60 years ago (Chisholm, 1998; Tizard & Rees, 1975), and progressively classified by clinicians and researchers in two distinct forms of atypical behaviour. These two patterns of behaviour currently fall under the labels of (a) reactive attachment disorder (RAD), characterised by a failure to seek or respond to comfort from caregivers when hurt or distressed, combined with highly withdrawn behaviour and emotional dysregulation, and (b) disinhibited social engagement disorder (DSED), characterised by a pattern of indiscriminate friendliness, with little reticence in approaching and interacting with unfamiliar adults and venturing away in unfamiliar settings (American Psychiatric Association, 2013; see also Zeanah & Gleason, 2015).

Conflict of interest statement: No conflicts declared.

Despite extensive evidence linking these two phenotypes with caregiving deprivation, particularly institutionalisation and repeated changes in caregivers, little is known about how such effects of early adversity become biologically embedded and neurally instantiated. In this study, we seek to replicate previous findings of the general effects of institutionalisation on neural processing of faces in settings that differ in important ways from those studied in most of the existing literature and to investigate the role of variation in the institutional experience and attachment disorder symptoms in that neural processing.

Neurodevelopmental consequences of institutionalisation

Existing evidence documents effects of institutionalisation on neurodevelopment. Indeed, reports of brain anatomical and functional differences between family- and institutionally reared children are accumulating. Limiting this work, however, is its focus on a small number of research sites, with most investigations based on children growing up in Eastern European institutions (Marshall, Fox, & the BEIP Core Group, 2004; Parker, Nelson, & The Bucharest

Early Intervention Project Core Group, 2005; Vanderwert, Marshall, Nelson, Zeanah, & Fox, 2010), even though a few studies also included institutionalised children in China and other parts of Asia (Hodel et al., 2015; Tarullo, Garvin, & Gunnar, 2011; Tottenham et al., 2011). The Bucharest Early Intervention Project (BEIP) offers the most robust findings due to its randomised design, though they might not be generalizable to all orphanage settings and populations, while most other research projects assessed children months to years after removal from the institution (cf. van IJzendoorn et al., 2020). Neuroscientific research employing event-related potential (ERP) to investigate institutionalised children's face processing, in particular, has thus far been limited to institutionalised children from the BEIP.

Whatever the indisputable strengths of this research project, questions arise as to whether existing evidence can be generalised to children residing in institutions in other countries, such as in Western Europe, and this is because Romanian institutions have been especially impoverished even by the early 2000s—including very poor ratios of children to caregivers (such as 30–35 children cared for by two–three caregivers in a "typical unit"), a regimented daily schedule, and a management structure led by medical personnel (IMAS & UNICEF Romania, 2004; Rosapepe, 2001; Smyke et al., 2007; Smyke, Dumitrescu, & Zeanah, 2002). In sharp contrast to Romanian institutions, Portuguese institutions that are the focus of this report generally offer higher quality care in regard to nutrition, access to therapies, and planned activities targeting cognitive stimulation. Critically, Portuguese caregivers are also responsible for significantly fewer children than in Romania, averaging six children per caregiver in the institutions of the current sample. Nevertheless, both the Romanian and the Portuguese institutions, like most such contexts, provide care that qualifies as "psychosocial neglect" in that there is substantial turnover in caregiving staff and lack of individualised care, limiting opportunities for children to establish close and positive attachment relationships with particular caregivers (Tarullo & Gunnar, 2005; The St. Petersburg-USA Orphanage Research Team, 2008; van IJzendoorn et al., 2020).

The adverse effects of institutional care on neurobiological and behavioural development are presumed to derive from this "psychosocial neglect" rather than limited nutritional or medical care. Indeed, evidence indicates that it is not global deprivation but other aspects of institutional rearing that have a major long-term effect on brain development as well as on attachment disordered behaviour (Bruce, Tarullo, & Gunnar, 2009; Lawler, Koss, Doyle, & Gunnar, 2016; Sonuga-Barke et al., 2008; Tarullo et al., 2011). Nevertheless, further research is needed, as knowledge is lacking regarding the consequences of early institutional rearing when deprivation is not as severe as in many institutions that have been the focus of inquiry (McCall, 2011; Woodhouse, Miah, & Rutter, 2018).

Face processing and institutionalisation

Research on the neurodevelopment of institutionalised children using electroencephalogram (EEG) and ERP often relies on tasks that employ facial stimuli. The focus on neural correlates of face processing in this population is explained by their putative atypical experience with faces as a result of being routinely exposed to multiple and changing caregivers (Gunnar, 2001). Faces are highly salient stimuli fundamental to children's social-cognitive development and involve neural circuitry known to be affected by developmental experience (Johnson & De Haan, 2015; Parker et al., 2005). Also, it is precisely this inconsistency in, and lack of individualised and dedicated care, so characteristic of institutional settings, that is associated with children's difficulty in forming focused attachments and the emergence of attachment disordered behaviour (Chisholm, 1998; O'Connor & Rutter, 2000; Smyke et al., 2002; Tizard & Rees, 1975; Zeanah et al., 2005).

The most striking result from EEG and ERP research with institutionally reared children in response to the presentation of visual stimuli is evidence of cortical *hypoactivation* in the brain electrical activity. Relative to family-reared controls, institutionally reared children from the BEIP have been found to show reduced amplitudes in ERP components involved in face processing, particularly the P1 that is thought to reflect early and low-level stimulus feature processing, and N170, a marker of face-sensitive perceptual processes that follow the P1 (Moulson, Fox, Zeanah, & Nelson, 2009; Moulson, Westerlund, Fox, Zeanah, & Nelson, 2009; Parker et al., 2005). Interestingly, the group of previously institutionalised children who were then placed in high-quality foster-care show intermediate P1 amplitudes between those of institutionalised and family-reared age-mates (Moulson, Westerlund, et al., 2009), clearly in line with the view that type and/or quality of caregiving are related to the amplitude of these ERP components.

Despite overall reduced ERP amplitudes during face processing in the BEIP findings above, institutionalised children showed differing neural responses to the caregiver and stranger faces, similar to the family-reared controls (Moulson, Westerlund, et al., 2009; Parker et al., 2005). However, previous work did not take into account individual differences in attachment or social difficulties, which we do herein. This may be important because in a small sample of foster-care children in Germany, variation in attachment security did play a role in children's face-familiarity processing: not only was a reduced N170 seen in foster-children compared to home-reared controls, [but] it was also seen in insecurely attached children compared to secure ones (Kungl, Bovenschen, & Spangler, 2017). Accordingly, measuring variations in socioemotional adaptation might illuminate the impact of early caregiving on neural development.

Face processing and attachment disordered behaviour

Several studies of institutionally reared children have analysed neuroimaging correlates of child functioning and psychopathology symptoms, but the neural substrates of social or attachment disordered behaviour have received only limited empirical attention. Two exceptions are an EEG study which found that a pattern of lower spectral power predicted later DSED-type behaviour in post-institutionalised children (Tarullo et al., 2011) and a functional magnetic resonance imaging (fMRI) study linking reduced amygdala differentiation between the mother's and a stranger's face with elevated levels of DSED symptoms in post-institutionalised, adopted youth (Olsavsky et al., 2013). Even if confounded by the *post*-institutional nature of the samples, such findings point to the potential importance of considering social/attachment disordered behaviour in the investigation of the neural processing of face familiarity in children exposed to such settings.

While we lack data on the neural correlates of RAD, there is reason to expect that the underpinning neural systems for RAD and DSED may be quite different, given that they show different behavioural features and developmental courses. Firstly, there seems to be a sensitive period for the emergence of DSED-type behaviour, and secondly, it tends to persist across time, often well after the major environmental change that is adoption occurs (Chisholm, 1998; Gleason et al., 2011; O'Connor & Rutter, 2000). In contrast, RAD seems to diminish substantially—and disappear in most cases—once the child moves to a more normative family environment (Zeanah & Gleason, 2015). Accordingly, it seems reasonable to expect that despite emerging from similar adverse early experiences, these two phenotypes—RAD and DSED—will have distinct neural correlates while processing socioemotionally relevant stimuli.

In our efforts to understand the distinctive neural processes associated with RAD and DSED, we previously conducted an exploratory analysis of a subset of the sample included in the current inquiry (Mesquita et al., 2015). Preliminary evidence indicated that Portuguese institutionalised children with RAD and/or DSED appear to have a smaller P1 than their non-RAD/DSED institutionalised peers, along with some additional evidence of reduced discrimination of stranger's and caregiver's faces in a small subgroup of children with DSED. However, it remains to be established which institutionalised children—those displaying RAD- or DSED-type behaviour or both—show altered ERP amplitudes (in the P1 as well as other components) when processing faces, and which fail to demonstrate distinctive neural processing patterns to the caregiver's versus stranger's face, when compared to family-reared children. A larger sample of institutionalised children and a reference group will allow us to examine these questions.

Current study

The current investigation aims to extend research on the face processing and social/attachment development of institutionalised children in several ways. The first is by evaluating whether neural correlates of face familiarity differ as a function of rearing experiences amongst currently institutionalised children in Western Europe by comparing them to a group of family-reared controls. Subsequently, we assess, amongst the institutionalised children, whether variation in social/attachment disordered behaviour (RAD and DSED behavioural symptoms) and in the institutional caregiving experiences predict face processing patterns. This design affords assessment of effects of both institutionalisation in general and RAD/DSED in particular on face processing.

On the basis of the research and reasoning considered through this point, we advance three sets of hypotheses. First, because Portuguese institutions also are characterised by psychosocial neglect, we predict that institutionalised children will show reduced ERP amplitudes, relative to family-reared children, on posterior components involved in face processing (P1, N170, and P400).

Second, we predict that smaller ERP amplitudes will be associated with severity of DSED symptoms (in line with Tarullo et al.'s EEG findings). Additionally and concerning face familiarity effects, we hypothesise (based on Mesquita et al., 2015; Olsavsky et al., 2013) that institutionalised children with DSED symptoms will fail to discriminate, at the neural level, the face of a stranger and that of the caregiver. However, we advance no specific hypotheses regarding RAD symptoms because we know much less about its underlying neurophysiological correlates.

The third set of hypotheses concerns variation in exposure to institutional care. We predict that children admitted earlier and who have been institutionalised longer will show especially reduced ERP amplitudes. Moreover, the same is expected of those exposed to particularly psychosocially deprived settings operationalised as higher children-to-caregiver ratios, indexing fewer opportunities for individualised caregiving.

Method

Participants

Institutionalised group. This study is part of a larger research project on the development of Portuguese institutionalised children, with approval by the Portuguese Social Services and the National Commission for Data Protection (Ref. 342/2010), as well as by the University of Reading Research Ethics Committee (Ref. 10/59). The institutionalised group (IG) consisted of children aged 3–6 years who had not yet entered primary school, who had been at the institution for ≥6 months, and who did not suffer from moderate to severe mental or physical impairments, genetic syndromes, or autism spectrum disorders. Written informed consent was requested from institution directors, biological parents, and participating caregivers. Of the 94 participants who underwent ERP testing, 24 had insufficient usable data due to excessive noise in the EEG or <25 good trials per condition.

The final sample for analysis included 70 children who were 36–79 months and came from 24 institutions. There were eight pairs of siblings and one group of three siblings. Children were admitted to the institution at 3–69 months of age, mostly because of neglect (83%) and a minority for physical abuse (9%), amongst other reasons. Children's birth families were almost exclusively of low socioeconomic status (SES). Every child participated with their caregiver, who was identified as the child's favourite staff member at the institution or (when such a person could not be identified) the one most familiar with the child and involved in his/her daily routines. In total, 57 female caregivers were enrolled in the study, with eight of them participating with more than one child.

These 24 institutions varied substantially in size, with an average of 19 children (range = 8–46) and 13 caregivers (range = 4–53). Ratios of children per caregiver were six in average and ranged 3–11. All institutions had a specialised leadership team that included a psychologist, and in most cases also a specialist in education and a dedicated social worker. All institutions reported dedicated time to play and learning, and for most (n = 22), it was part of the caregivers' role to devote some time exclusively to play. See Table 1 for sample description.

Family-reared group. A comparison group of family-reared children from the community (CG) was recruited from the local community, including a range of diverse sociocultural backgrounds. The same health and mental developmental exclusion criteria applied, in addition to the required absence of any child protection measure or history of institutionalisation. CG children participated with their mothers. Of the 55 families contacted, 21 refused to participate, cancelled, or did not attend the assessment. Families that did and did not participate did not differ in SES. Of the 34 children who underwent ERP testing, four did not have sufficient usable data due to excessive noise in the EEG or had <25 good trials per condition. The final CG consisted of 30 children, aged 40–75 months old. There were two pairs of siblings. All except one child went to preschool. The majority of children (n = 25, 83%) lived with both biological parents, but five children (17%) lived with the mother and other family members (step-father or grandparents/uncle and aunt).

Measure of disordered attachment in institutionalised children

The disturbances of attachment interview (DAI). The DAI (Smyke & Zeanah, 1999) is a semi-structured interview, administered to caregivers, to evaluate the presence of signs of disordered attachment. For each item, a rating of 0, 1, or 2 is given according to the degree of evidence of disturbed or disordered attachment. Questions 1–5 pertain to withdrawal/inhibited attachment behaviour and will be taken as an indication of RAD (e.g., lack of active and selective comfort seeking when hurt/upset). Questions 6–8 pertain to disinhibited behaviour and will be taken as an indication of DSED (e.g., would readily go off with an unfamiliar adult). Cohen's kappa to assess inter-rater reliability (n = 37) was acceptable for the inhibited and disinhibited behaviour items (M = .63 and M = .75, respectively).

ERP assessment

Task stimuli and procedure. Stimuli were photographs of the child's caregiver/mother and a female stranger, posing a neutral expression. Photographs were edited to standardise background, size, brightness, and contrast. The experimental paradigm was designed according to Todd, Lewis, Meusel, and Zelazo (2008), and a more detailed description can be read in the Appendix S1. The *Presentation* (Neurobehavioural Systems Inc, Berkeley, CA, USA) software was used to create and present the task.

Children visited the laboratory with their caregiver for this assessment and sat in front of the computer screen, at a distance of 100 cm. A researcher remained in the room monitoring and recording the child's behaviour and attention and the quality of the EEG signal. If necessary, the researcher coached the child to maintain attention or remain still. The caregiver also remained in the room, behind the child. The experimental paradigm lasted 30 min. Recordings were conducted for the total duration of the task unless the child became too fussy, sleepy, or refused to continue.

EEG recording and processing. The EEG was recorded with the Brain Vision Recorder system using a Quickamps amplifier with 32 sintered Ag/AgCl electrodes placed according to the extended 10–20 International System. The EEG data were analysed with Brain Vision Analyser software (Version 2.0.1). See the Appendix S1 for further details on data acquisition and analysis.

Corrected artefact-free trials were averaged for each subject in each condition (neutral caregiver's face and neutral stranger's face). Groups did not differ in average number of included trials (IG = 49 and 50 and CG = 48 and 48 for the caregiver and stranger conditions, respectively). Mean amplitudes for the P1, N170, and P400 components were identified

Table 1 Participants' descriptive statistics

	Gender (n male)	Age M (SD)	Mental age M (SD)	Ethnicity (% Caucasian)	Age at admission M (SD)	Time institutionalised M (SD)	RAD total	DSED total
CG (n = 30)	13	57.93 (10.52)	63.89 (10.48)	100	–	–	–	–
IG (n = 70)	47	57.94 (11.67)	58.55 (12.13)	74	38.16 (14.30)	20.14 (12.12)	1.93 (1.59)	1.13 (1.64)

All age and time variables are in months. CG, Community group; DSED, disinhibited social engagement disorder; IG, Institutionalised Group; RAD, reactive attachment disorder.

in these time windows after stimuli onset: 80–150 ms, 151–300 ms, and 301–550 ms, respectively, at electrode sites O1 and O2 (occipital), and PO9 and PO10 (parieto-occipital). See averages of peak and mean amplitudes in the Table S1. These sites, which are in line with the literature (e.g., Conte et al., 2020; Kungl et al., 2017; Moulson, Fox, et al., 2009; Moulson, Westerlund, et al., 2009), can be verified in the scalp topographies provided in the Figure S1.

Statistical analysis. We followed the procedures proposed in Luck et al. (2021) to obtain standardised measurement error (SME) metrics of the quality of the ERP data. These suggested that our data were "noisier" for peak amplitudes and latencies than for mean amplitudes; therefore, we opted for analysing the latter (see Table S2). Comparison of SMEs across the CG and IG revealed no group differences. Inspection of participants' individual SMEs allowed the identification of "noisier" recordings (defined here as those with SMEs greater than the standard deviation (*SD*) of the mean amplitudes for those sites, but see Luck et al. (2021) for a discussion on how to interpret SMEs in this context), which were excluded from further analyses ($n = 3$ from the CG and $n = 2$ from the IG).

For group comparisons (hypotheses set 1), repeated measures analysis of variance (ANOVA) with a mixed design were computed for each of the ERP components, with mean amplitude (in μV) as the dependent variable. The within-subjects factors were face (caregiver's/ stranger's) and hemisphere (left/ right), and the between-subjects factor was group. Significant main group effects and interactions were followed-up with planned contrasts with a Bonferroni correction for multiple comparisons.

The same analysis plan was used for intra-group analyses of the institutionalised children, with RAD and DSED (hypotheses set 2), as well as variables of the institutional caregiving experience (hypotheses set 3), entered in the repeated measures ANOVAs as continuous between-subjects variables.

A complete analysis plan can be found in the Appendix S1.

Results

See Figure 1 for the grand means of ERPs exhibited by each group, per condition and electrode. Descriptive statistics of the mean and peak amplitudes for each group and condition are provided in the Table S1.

Group differences in ERPs to face stimuli between institutionalised and family-reared children (hypotheses set 1)

See Table 2 for coefficients.

P1. There was a faceXhemisphere interaction and a faceXhemisphereXgroup interaction. Inspection of means and plots revealed that only the CG (not the IG) showed discrimination between the two faces in amplitude and hemispheric asymmetry, namely, larger P1 to stranger's than caregiver's face and

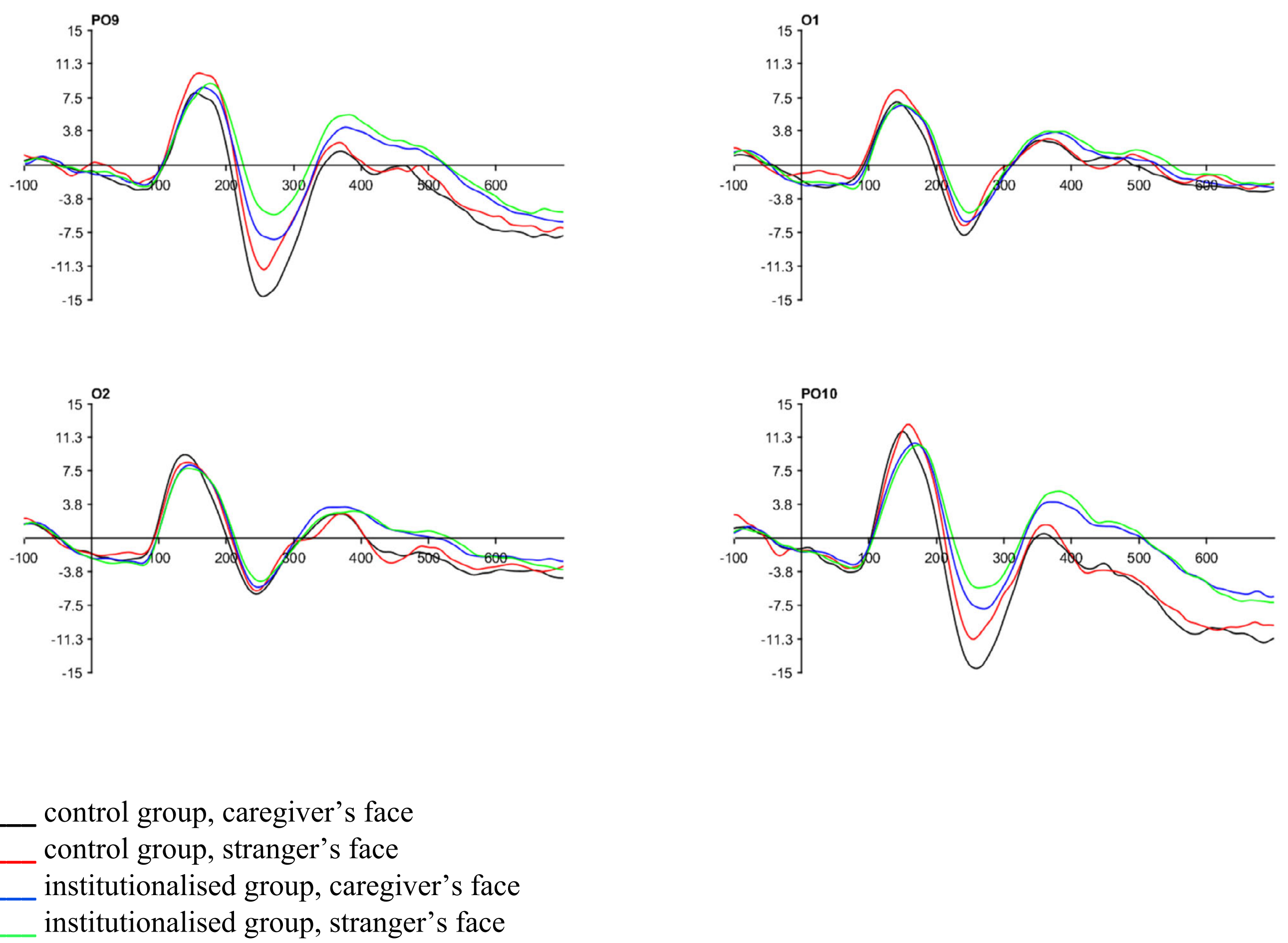

Figure 1 Grand means of ERPs exhibited by each group, per condition, over the left and right occipital and parieto-occipital electrodes. Amplitude in μV on the *y*-axis and latency in ms on the *x*-axis

Table 2 ANOVA summary table for hypothesis set 1 significant effects

Source	*df*	*F*	*p*	Effect size (η_p^2)
P1 mean amplitude				
Face × hemisphere	1, 93	7.44	.008	.07
Face × hemisphere × group	1, 93	5.61	.020	.06
N170 mean amplitude				
Group	1, 93	5.62	.020	.06
Face	1, 93	15.08	< .001	.14
P400 mean amplitude				
Group	1, 93	6.57	.012	.07
Hemisphere	1, 93	7.21	.009	.07
Group × hemisphere	1, 93	7.76	.006	.08

The between-subjects factor was group.

right asymmetry to caregiver's (but not stranger's) face.

N170. There was a main effect of group. The CG showed larger amplitudes (i.e., more negative) than the IG. Group effects held when controlling for age and mental age in follow-up analyses (see Appendix S2).

There was also a main effect of face. Regardless of group, N170 amplitudes were larger for the caregiver's than stranger's face.

P400. There were main effects of group and hemisphere, which were qualified by a groupXhemisphere interaction. The IG showed larger amplitudes than the CG, particularly over right leads. Group effects held when controlling for age and mental age in follow-up analyses (see Appendix S2).

Within institutionalised group associations between ERPs and children's attachment difficulties (hypotheses set 2)

See Table 3 for coefficients.

RAD. P1, N170 and P400: No significant effects.

DSED. P1: There was a main effect of DSED for this ERP component. Smaller P1 amplitudes were associated with increased DSED symptoms. This result held when controlling for developmental age or age (see Appendix S2).

N170: There was a main effect of face, which was qualified by a faceXDSED interaction. To clarify this interaction, we ran a regression analysis for each face separately, with DSED symptoms as a single predictor, but neither was significant (all $p > .1$).

There was also a main effect of hemisphere. N170 amplitudes were larger over left than right leads amongst all institutionalised children.

Table 3 ANOVA summary table for hypothesis set 2 significant effects

Source	*df*	*F*	*p*	Effect size (η_p^2)
DSED				
P1 mean amplitude				
DSED	1, 66	4.75	.033	.07
N170 mean amplitude				
Face	1, 66	11.81	.001	.15
Face × DSED	1, 66	7.26	.009	.10
Hemisphere	1, 66	4.35	.041	.06
P400 mean amplitude				
Face	1, 66	7.39	.008	.10
Face × DSED	1, 66	9.97	.002	.13

The between-subjects factor was DSED. DSED, disinhibited social engagement disorder.

P400: There was a main effect of face, which was qualified by a faceXDSED interaction. To clarify this interaction, we ran separate regressions for each face. Increased DSED symptoms predicted a smaller P400 amplitude to the stranger's face (β = −.25, p = .040), but did not predict the amplitude to the caregiver's face (β = −.03, *n.s*). A follow-up regression of the difference scores between the two faces revealed that increased DSED symptoms significantly predicted reduced P400 differences between stranger and caregiver faces (β = −.36, p = .002). All significant results held when controlling for developmental age or age (see Appendix S2). This means that increased DSED symptoms were associated with a smaller difference between P400 amplitudes to each face and with a smaller P400 amplitude to the stranger's face specifically.

Within institutionalised group associations between ERPs and children's institutional experience (hypotheses set 3)

See Table 4 for coefficients.

Age at admission and time institutionalised. P1, N170, and P400: There were no main or interaction effects of age at admission or time institutionalised on P1, N170, or P400 amplitudes.

Table 4 ANOVA summary table for hypothesis set 3 significant effects

Source	*df*	*F*	*p*	Effect size (η_p^2)
Ratio children/caregivers				
N170 mean amplitude				
Face	1, 66	4.66	.035	.07
P400 mean amplitude				
Ratio	1, 66	8.15	.006	.11
Face	1, 66	4.42	.039	.06

The between-subjects factor was ratio of children-to-caregivers.

Ratio of children-to-caregivers. P1: No significant effects.

N170: There was a main effect of face on N170 amplitude, with larger amplitudes to caregiver's than stranger's face. There was no main effect nor any interactions involving ratio for this ERP component.

P400: There was a main effect of ratio on P400 amplitude. A higher ratio of children-to-caregivers predicted smaller P400 amplitudes. This result held when controlling for age and mental age in follow-up analyses (see Appendix S2).

There was also a main effect of face. P400 amplitudes were slightly larger for the stranger's than caregiver's face amongst all institutionalised children.

We conducted additional sensitivity analyses in which one sibling was removed from the sample and the results were not substantively different.

Discussion

The research reported herein investigated the neural correlates of face familiarity processing in institutionalised children and their association with symptoms of RAD and DSED. More specifically, we sought to replicate previous findings of the general effects of institutionalisation on neural processing of faces in institutional settings that differ in important ways from existing work—by deprivation being less severe, even if indisputably present—and to illuminate the role of variation in individual institutional experience and social/attachment disordered behaviour in that neural processing.

Group comparisons

Recall that a focus on group comparisons was based on the prediction that institutionalised children would show reduced ERP amplitudes compared to children continuously raised by their families. Even though we failed to detect a significant difference for the P1, we did, as expected, find smaller amplitudes in the N170 component in institutionalised children. Contrary to our predictions, we did not observe a reduction in amplitudes amongst institutionalised children in the rest of the ERP epoch; rather, for the P400 component, amplitudes were actually larger in institutionalised than in control children. We discuss these results next.

Group differences in the P1 did not reach statistical significance, but inspection of the grand averages (Figure 1) suggests that institutionalised children had somewhat smaller amplitudes (particularly for the stranger's face) than controls. For the N170, institutionalised children did show significantly smaller mean amplitudes than controls, and this effect was seen across both faces (caregiver's and stranger's) and held when taking absolute and developmental age into account—suggesting that it was not just a product of group differences in developmental level. In the BEIP sample, a larger N170 in never-institutionalised children than in institutionalised children was evident at the baseline (when children were 7–32 months), but group differences at later assessments were confounded by age (Moulson, Westerlund, et al., 2009; Parker et al., 2005). In a small but unique investigation of German foster children of similar age to those in the current study, foster children showed a blunted N170 (but no difference in the P1) to both caregiver and stranger's face, when compared to children living with their biological families (Kungl et al., 2017).

Our finding of a blunted N170 in currently institutionalised Portuguese children provides for the first time evidence of differences in face-sensitive perceptual processes, amongst children who entered relatively higher-quality institutions than those which have been the focus of much other related work (e.g., Moulson, Westerlund, et al., 2009; Parker et al., 2005), later in development and for largely different reasons than those in previous research.

However, and contrary to our predictions, institutionalised children showed larger P400 mean amplitudes than controls. Before we speculate on explanations for group differences in processing indexed by the P400, it is important to highlight the possibility of this not reflecting a true effect. When inspecting our grand average figures, it is apparent that there might be a carry-over effect from the N170, and thus interpretation of P400 group differences warrants caution.

We will, however, offer some tentative explanations, pending replication of this group difference in future studies. Because the P400 is a face-sensitive component hypothesised to be, in part, a developmental precursor to the N170 (Conte et al., 2020; Halit, de Haan, & Johnson, 2003), it is not implausible that developmental delay in institutionalised children explains their reliance on later or less specific neural processes as indexed by the P400, while controls' face processing is potentially underpinned by more mature neural responses, including a more adult-like sequence of face-sensitive components. Alternatively, or relatedly, it might be that institutionalised children's reliance on later neurocognitive processes for perceiving faces (as indexed by a larger P400) either indicates a deficit or an adaptation to their environment. Yet, as seen above, these explanations are merely speculative at this point, as it is not clear whether group differences in P400 reflect a true effect in this sample.

We now turn to discuss face effects. Consistent with previous research (Moulson, Westerlund, et al., 2009; Parker et al., 2005), we found evidence of face discrimination in institutionalised children, specifically in N170 amplitudes (larger for the caregiver's face). Despite challenges in interpreting the direction of amplitude differences due to an inconsistent literature likely confounded by developmental changes (Caharel et al., 2002; Moulson, Westerlund, et al., 2009; Todd et al., 2008), the existence of a same-age control group affords confidence that institutionalised children's ability to discriminate the two faces at the neural level, as detected by the N170 component, is preserved.

Nevertheless, face effects in the P1, specifically differences between faces in amplitude (larger for the stranger's) and hemispheric asymmetry (greater right-sided P1 involvement for face processing as is commonly reported, e.g., Taylor, Batty, & Itier, 2004) were seen in controls but not in institutionalised children. The P1 is involved in the early stages of visual sensory response to stimuli and is sensitive to the individual's state of arousal (larger amplitude associated with higher arousal) and to allocation of attentional resources to those stimuli (Hillyard, Vogel, & Luck, 1998; Mangun, 1995; Vogel & Luck, 2000), while it is not reliably influenced by familiarity (Marzi & Viggiano, 2007). Therefore, it would be important to replicate these findings with other, non-face stimuli to disentangle effects of arousal to novelty and salience from face familiarity–specific effects.

Within institutionalised group analyses

A major aim of the research reported herein was to investigate links between neural processing of faces and institutionalised children's display of RAD and DSED symptoms. Recall, first, that we found that RAD symptoms did not predict any ERP components. In contrast, higher levels of DSED symptoms predicted (a) smaller P1 amplitudes (regardless of face) and (b) smaller P400 differences in amplitude to each face, as well as a smaller P400 amplitude in response to the stranger's face specifically—even after controlling for age and mental age. These findings are in line with the prediction of a link between DSED and alterations in the underpinnings of face familiarity processing, while providing unique evidence of a clearer role of a neurobiological basis of DSED (Rutter et al., 2004, 2007; Sonuga-Barke et al., 2008) than RAD.

The association of a reduced P1 with DSED symptoms might mean that the face stimuli elicit less arousal for socially disinhibited children and/or be related to attentional differences in these children even when compared to their institutionalised counterparts (Slopen et al., 2012; Vogel & Luck, 2000). The intra-group association between P400 and DSED (as well as caregiving quality, see last paragraph in this subsection) suggests that this component is implicated in interpersonal or social outcomes. Whether such individual differences are specific to face processing or more general neural processing deficits amongst Portuguese institutionalised children is not possible to know until further research becomes available.

Our findings of an association between reduced P1 and P400 amplitudes and DSED (but note that in the case of the P400, this was only in response to the stranger's face) are in line with existing EEG and fMRI evidence. Tarullo et al.' (2011) found that a power concentration in lower frequency bands predicted DSED-type behaviour in post-institutionalised children. Even though further research is needed to support this interpretation, together these findings preliminarily suggest an association between cortical hypoactivation and DSED-type behaviour amongst institutionally reared children, beyond their institutionalisation experience per se.

The association that we discerned between DSED and reduced neural differentiation between the two faces in P400 amplitudes is in agreement with Olsavsky et al.' (2013) fMRI finding of a similarly reduced differentiation at the level of amygdala activity in post-institutionalised youth. The reduced discrimination between the familiar and unfamiliar faces at the neural level may thus become a preliminary neural marker of the indiscriminate friendliness observable in these children's behaviour.

In conclusion, we found indicators of altered patterns of neural processing in response to faces associated with DSED, for the P1 and P400, but not for the N170 which is where we found more reliable differences between institutionalised and control children. In addition, the link between P1 and DSED was irrespective of face, suggesting it could reflect a more general difficulty with attention in these children (the link between inattention and DSED has received considerable attention, e.g., Bruce et al., 2009; Love et al., 2015; MacLean et al., 2003). However, the link between DSED and a reduced neural discrimination between the faces in the P400, and a reduced amplitude in response to the stranger's face specifically, suggests that this component is indexing a face-specific alteration in neural processing that is relevant for our understanding of this behavioural pattern, in terms of indiscriminate approach of strangers and lack of developmentally expected stranger weariness. To clarify, the P400 has not only been hypothesised to partly precede the maturation of the N170 but has also been implicated in novelty detection, with greater amplitudes seen in response to novel than familiar faces in some studies (Conte et al., 2020). Therefore, our results could mean that for children with higher DSED, the stranger's face elicits reduced novelty-triggered neural processes.

Our third set of analyses investigated the role of institutional experiences in children's neural processing of the face stimuli. Despite the variability in age at admission to the institution and length of time institutionalised in this sample, these were variables that did not help explain children's ERPs. Even though it was not possible to explore the existence of early sensitive periods due to the relatively old age at which children entered the institutions, the absence of linear “dose” effects of institutional deprivation is in line with more recent findings from the English and Romanian Adoptees study. Specifically, poorer cognitive and social development (including DSED-type behaviour) has been reported for children institutionalised beyond 6 months of age, with no discernible differentiation within the 6–42-month range (Kreppner et al., 2007; Rutter et al., 2007). Nevertheless, children in the current study were still institutionalised when they were assessed, so comparisons with post-institutionalised adoptees are limited.

In contrast to the null effects of timing and duration of institutionalisation on ERPs, it was variation in individualised care that predicted children’s neural responses in the current study. Specifically, living in a setting with poorer ratios of children-to-caregivers (i.e., more children per adult) predicted smaller P400 amplitudes to either face stimuli. These results support the case for not assuming that all institutional settings have identical effects on development (Oliveira, Fearon, Belsky, Fachada, & Soares, 2015) but ultimately provide additional evidence that institutional deprivation resulting from lack of one-to-one interactions is a key factor contributing to children’s poor socio-emotional functioning, by limiting opportunities for individualised attention and consistent relatedness from a stable caregiver (Tarullo & Gunnar, 2005).

Conclusion

ERP studies such as this one are important to identify neural mechanisms involved in children’s socio-emotional difficulties associated with early caregiving adversity. The evidence presented here adds to a growing body of work that is progressively painting a more precise picture showing that social neglect—particularly reduced individualised care—has a deleterious impact on children’s neural processing of faces. The current study also demonstrated for the first time that a pattern of reduced ERP amplitudes and reduced neural discrimination between faces is associated with institutionalised children’s DSED, but not RAD symptoms.

Limitations

The current study is limited in several ways. Importantly, even though we were only interested, for this report, in children’s face familiarity processing (i.e., responses to neutral caregiver and stranger’s faces), the ERP task included additional face stimuli, posing emotional facial expressions. The fact that these neutral faces were presented amongst happy and sad faces may have influenced results; therefore, subsequent analyses of the neural processing in response to the emotional faces will be needed to extend and generalise the conclusions from the current report. In addition, our ERP task also included a go/no-go component; however the cues and response to this component happened outside of the epoch analysed herein.

There were a few important differences between the groups. In addition to the unbalanced sample sizes across groups, there were ethnicity differences, with the institutionalised, but not the control group, including non-Caucasian children. Finally, only institutionalised children were assessed for disordered attachment behaviour. While current understanding of RAD and DSED restricts them to situations where the child has experienced patterns of extreme insufficient care to which the home-reared children were not exposed, their scores on the RAD/DSED symptoms measure, though likely to be low, are unknown.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Appendix S1. Method – further detail.
Appendix S2. Results – follow-up sensitivity analyses.
Figure S1. Scalp topographic maps for the three windows under analysis.
Table S1. Averages of peak and mean amplitudes (in μV) for each group and condition.
Table S2. Averages of the root mean square (standardised measurement error).

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Key points

- Existing evidence of neural face processing in institutionalised children has previously been limited to settings of severe deprivation and the role of social/attachment behaviour scarcely investigated.
- We replicated findings of blunted amplitudes in a posterior component involved in face processing, in a less globally deprived setting than past work.
- Reduced ERP amplitudes and reduced neural differentiation between faces were associated with DSED, but not RAD, symptoms.
- Reduced ERP amplitudes were associated with exposure to a higher children-to-caregivers' ratio.
- These findings indicate that differences in neural processing of faces are associated with lack of individualised care, even in the absence of other types of deprivation, and with DSED.
- Interventions should address the deleterious interpersonal experience of being cared for by multiple caregivers but lacking one-to-one interactions, to which institutionalised children are exposed.

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