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Title

Neural Correlates of Face Familiarity in Institutionally Reared Children With Distinctive, Atypical Social Behavior

Permalink

https://escholarship.org/uc/item/9qs26635

Journal

Child Development, 86(4)

ISSN

0009-3920

Authors

Mesquita, Ana R
Belsky, Jay
Crego, Alberto
et al.

Publication Date

2015-07-01

DOI

10.1111/cdev.12371

Peer reviewed

Neural correlates of indiscriminate social behavior in institutionalized children: Comparison to children with inhibited behavior and to a family-reared group/ Neural correlates of face familiarity in institutionalized children with indiscriminate behavior: Comparison to other/fellow institutionalized and to family-reared children

PERHAPS WE ARE BEST OFF WITH JUST A SHORT TITLE THAT DOESN'T GET INTO GORY DETAILS ABOUT COMPARISON GROUPS

Introduction

Early institutionalization, which generally entails exposure to at least some form of psychosocial neglect, is known to compromise multiple aspects of children's development. The socio-emotional realm is perhaps the most adversely affected, proving and resistant to change, even following post-institutional placement (Bakermans-Kranenburg et al., 2011). One of the most well-documented sequelae of this early adverse experience is the display of inappropriately friendly and trusting indiscriminate social behavior directed indiscriminately toward both familiar and unfamiliar adults alike. Despite extensive evidence linking this indiscriminate-social-behavior phenotype with institutionalization, little is known about how such effects of early adversity becomes biologically embedded and neurally instantiated. Here we thus explore the neurobiological bases of indiscriminate social behavior to elucidate effects of institutionalization on brain development. Specifically, we compare ??? with ??? on ???; we predicted that ????

SAY A LITTLE MORE ABOUT THE DESIGN HERE—ERP IN FACE FAMILIARITY PARADIGM, WITH COMPARISON GROUPS?

Institutional rearing and indiscriminate social behavior

Socially disinhibited or indiscriminate behavior (IB) is a pattern of indiscriminate friendliness and lack of selectivity in seeking proximity to and comfort from adults. Lacking in children displaying such behavior is , without the normal wariness of strangers, coupled with a and with disregard for social, physical or verbal boundaries. Disinhibited Social Engagement Disorder (DSED) is how The DSM-V (American Psychiatric Association, 2013) labels this behavioral pattern, of Disinhibited Social

~~Engagement Disorder (DSED),~~ specifying its etiology as involving the experience of insufficient care.

DSED ~~This disordered behavior~~ is distinguished from Attention-Deficit/ Hyperactivity Disorder (ADHD) and Reactive Attachment Disorder (RAD) in two principal ways. First, general impulsivity is not considered a core feature of DSED, as it is in ADHD, although it may be present; instead, DSED is typified by disinhibited social behavior directed~~s~~ towards unfamiliar adults. Second, whereas disinhibited/indiscriminate and emotionally-withdrawn/inhibited behavior were once considered two different presentations of the same underlying RAD (American Psychiatric Association, 1987, 2000), the most recent version of DSM (DSM-V, American Psychiatric Association, 2013) distinguishes the two. ~~t~~The inhibited form~~, which~~ retains the RAD label, while ~~and~~ the disinhibited/indiscriminate form~~, which~~ is considered a disorder of the social realm ~~and~~ thus labeled DSED.

Even if debate continues as to whether IB is ~~Notwithstanding ongoing debates regarding the conceptualization of IB as~~ indicative of disturbances in attachment or social engagement (~~for a recent discussion~~ see Lyons-Ruth, 2015; Zeanah & Gleason, 2015), there is clear evidence that IB is linked to institutional rearing and~~or to~~ multiple foster placements. These rearing environments represent~~are~~ extreme versions ~~s~~ of species-atypical experiences, as~~in that~~ they typically fail to provide ~~deprive~~ children with ~~of sustained access to~~ individualized and responsive caregiving provided by one~~from one~~ (or a few) consistent and committed caregiving adult(s). Indeed, elevated rates of IB have been repeatedly observed in different institutionalized samples, with varying levels and types of deprivation (e.g., Chisholm, 1998; O'Connor, Rutter, & The ERA Study Team, 2000; Tizard & Rees, 1975; Zeanah, Smyke, & Dumitrescu, 2002). In fact, despite reliance on ~~Even though investigators have used~~ different measurement instruments with non-standard clinical cut-off criteria, ~~it remains the case that~~ there is considerable agreement across investigations~~as to regarding~~ what behaviors are indicative of IB. Moreover, there is ~~, as well as~~ substantial convergence between measures of IB, ~~—~~both within studies (Bruce, Tarullo, & Gunnar, 2009; Gleason et al., 2011; Oliveira et al., 2012) and across ~~between~~ them (Zeanah et al., 2002).

Neurodevelopmental consequences of institutionalization

~~The fact that~~ IB tends to persist across time, even following adoption ~~often well after the major environmental change that is adoption~~ (Chisholm, 1998; Gleason et al., 2011; Kreppner et al., 2010; O'Connor et al., 2000). This observation, coupled ~~, along~~ with evidence suggesting the presence of a sensitive period in its development (REF NEEDED), make a strong case for investigating the neural substrates that underlie the association between the institutionalization~~environmental exposure~~ and the emergence and/ or maintenance of indiscriminate ~~such~~ behavior (Rutter et al., 2007; Rutter & O'Connor, 2004) ~~. Indeed, p~~ Prolonged institutionalization is presumed to affect brain structure and functioning in ways that enable the developing child to adapt to its~~their~~ unique environmental circumstances. Thus, ~~More specifically,~~ the readiness to approach and even be comforted by unfamiliar individuals ~~IB~~ is considered an adaptive ~~regarded as a~~ response to the multiple and frequently changing caregivers so characteristic of institutional life (Marshall & Kenney, 2009; Rutter & O'Connor, 2004). ~~The hypothesized neurobiological response, operating during a sensitive period in development, is presumed to reflect experience-dependent programming and may account for the persistence of IB following changes in the rearing environment (Rutter et al., 2007; Rutter & O'Connor, 2004). Understanding such biological embedding of early experiences at the level of brain structure and function is an important goal of developmental neuroscience.~~ Existing evidence documents ~~There is already substantial evidence of~~ effects of institutionalization on neurodevelopment. Indeed, reports of brain anatomical and functional differences between family- and institutionally-reared children are accumulating rapidly (Behen et al., 2009; Chugani et al., 2001; Eluvathingal et al., 2006; Gee et al., 2013; Govindan, Behen, Helder, Makki, & Chugani, 2010; Hodel et al., 2015; Maheu et al., 2010; Mehta et al., 2009; Sheridan, Fox, Zeanah, McLaughlin, & Nelson, 2012; Tottenham et al., 2011; Tottenham et al., 2010).

Limiting this work, however, is its focus on a small number of study sites, with most such work based on children growing up in Eastern European institutions (e.g., **2 refs needed**); several investigations are also based on institutionalized children in China and other parts of Asia (e.g., **2 refs needed**). Research such as that reported herein-- focused on ~~with most studies involving institutionalized children from Romania~~Eastern Europe, however a minority also included participants from China and other Asian

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~~countries. Studies employing E~~ event-related potentials (ERP) during face processing~~--;~~ ~~in particular,~~ ~~is~~ are limited to institutionalized children from Romania. In view of the fact that Romanian institutions are known to have ~~, a country where institutional care is known to have~~ been especially impoverished—in multiple ways—the question arises as to ~~. This raises the question of~~ whether evidence from these samples can be ~~would~~ generalized to children residing in Western European institutions. Not only are most western institutions less deprived than those in Eastern Europe, but children are often admitted to them at different ages and for different reasons than was the case elsewhere. ~~, where reasons for and age at admission differ from those in Eastern Europe during and even following the Communist era, and in which the quality of institutional care is likely to be better. Indeed, d~~

Despite substantial improvements due to the post-1990 reforms, the Romanian institutions of ~~in~~ the early 2000s were typically ~~still often~~ crowded and disorganized, being part ~~in the midst~~ of a system under transformation that was ~~but~~ still quite fragile in terms of funding and policy. In Bucharest in particular, institutions had, despite some variation, ~~in spite of considerable variability between centers and even between different units of the same institution, common features were~~ high ratios of children to caregivers —such as 30-35 young children being cared for by 2-3 caregivers in a "typical unit"~~-- (e.g. toddlers and preschool children in a "typical unit" were tended in a group of 30 to 35 children by 2 to 3 caregivers),~~ a regimented daily schedule, and a management structure led by medical personnel (IMAS & UNICEF Romania, 2004; Rosapepe, 2001; Smyke, Dumitrescu, & Zeanah, 2002; Smyke et al., 2007; Zeanah et al., 2003). This contrasts markedly with the Portuguese institutions that ~~is somewhat different from~~ are the focus of ~~taking part in~~ the current study. They generally offer~~, where~~ higher ~~general~~ quality of care ~~(notwithstanding variation across institutions) is high~~ in regard to nutrition, access to therapies, AND planned activities targeting cognitive stimulation, including ~~and~~ outdoor play. Portuguese caregivers are also responsible for fewer children (i.e., better caregive-: child ratio). ~~, for example, as well as lower ratios of children per caregiver (please see more details under Participants).~~ Nevertheless, both the Romanian and the Portuguese institutions, like most such ~~as most institutional~~ contexts, provide care that qualifies as "psychosocial neglect" in that there is substantial turnover in caregiving

staff and children typically do not establish close, attachment-like relationships with particular caregivers. **REVISE THE ENDING OF THE PRECEDING SENTENCE AS YOU SEE FIT IF IT IS NOT QUITE ACCURATE.** share what has been referred to as psychosocial neglect.

It seems reasonable to postulate that alterations in neurodevelopment—just as in the case of behavioral functioning—result from exposure to psychosocial neglect more than from global deprivation within the institution. This is because That is, adverse effects of institutional care on neurobiological and behavioral development are presumed to derive from the absence of dedicated caregiving by one or a few adults rather than limited nutritional or medical care and other aspects of the institutional experience. Consistent with this claim is der, for instance, recent evidence indicating that while that the quality of social care that post-institutionalized children received in the institution did not predict , but not growth-stunting, considered (an index of global deprivation), it was associated with IB following departure from the institution (Lawler, Koss, Doyle, & Gunnar, 2016). If the same applies to neurodevelopment, we can expect that children placed in generally good-quality institutions that meet children's basic physical needs, yet still lack dedicated caregiving, will nevertheless show altered neural activation patterns, particularly in networks implicated in socio-emotional processing. Consistent with this claim is evidence from the English and Romanian Adoptees (ERA) study. It indicates that prolonged institutionalization is associated with severely reduced head circumference, (a proxy of brain growth), even when there is no evidence of insufficient nutrition. Such data suggest that it is not global deprivation but other aspects of institutional rearing that have a major long-term effect on brain development (Sonuga-Barke et al., 2008).

Electroencephalography, face processing and institutionalization

Research on the neurodevelopment of institutionalized children using electroencephalogram (EEG) and Event-Related Potentials (ERP) often relies on tasks that employ facial stimuli. The focus on ERP correlates of face processing in this population emerged for several reasons. The first is related to the ecology of institutions; because children are routinely exposed to multiple and changing caregivers (Gunnar, 2001; van IJzendoorn et al., 2011), their experiences with familiar and unfamiliar faces are likely very different from those of children continuously reared in their families. Also,

it is precisely inconsistency in care, characteristic of institutional settings, that is associated with children's difficulty in forming focused attachments (Tizard & Rees, 1975; Zeanah, Smyke, Koga, Carlson, & The BEIP Core Group, 2005) and the development of IB (Chisholm, 1998; O'Connor et al., 2000; Smyke et al., 2002; Tizard & Rees, 1975). Additional reasons for studying the neurological bases of facial processing are that faces are highly salient stimuli, being fundamental to children's social-cognitive development, and involve neural circuitry known to be affected by developmental experience (Johnson & de Haan, 2011; Nelson, 2001; Parker, Nelson, & The BEIP Core Group, 2005a).

Evidence of cortical hypoactivation in response to ???? stimuli comes from EEG and ERP research on institutionalized children. Most such work has been ~~EEG and ERP research related to institutional rearing, mostly~~ carried out on the Romanian sample from the Bucharest Early Intervention Project ~~(BEIP) provides evidence of cortical hypoactivation among institutionalized children~~ (BEIP; e.g.,. Marshall, Fox, & the BEIP Core Group, 2004; ~~Moulson, Fox, Zeanah, & Nelson, 2009a; Moulson, Westerlund, Fox, Zeanah, & Nelson, 2009b; Parker et al., 2005a;~~ Parker, Nelson, & The BEIP Core Group, 2005b; Vanderwert, Marshall, Nelson, Zeanah, & Fox, 2010), but ~~—but see~~ Tarullo, Garvin, and Gunnar (2011), studying ~~for a notable exception of a study with~~ a different sample, reported similar results. ~~—provides evidence of cortical hypoactivation among institutionalized children.~~ Smaller ERP amplitudes have proven characteristic of ~~been documented in~~ institutionally reared children relative to home-reared ~~, compared to~~ controls ~~,~~ in posterior components implicated in face processing, such as the P1, N170 and P400. The P1 is an early-positive component that represents a sensory response to visual stimuli (Luck, 2005), one believed to reflect low-level stimulus feature processing (Marzi & Viggiano, 2007). The N170 is a negative peak that follows the P1 and is a marker of face-sensitive perceptual processes, corresponding to the structural encoding stage (Eimer, 2011; Kuefner, de Heering, Jacques, Palmero-Soler, & Rossion, 2010). The P400 is also face-sensitive and hypothesized to be ~~partly constitute~~ a developmental precursor to the N170 (Halit, de Haan, & Johnson, 2003).

One of the most notable results indicative of ~~such~~ cortical hypoarousal while processing faces emerged in the BEIP project when children were 30 and 42 months of

age. At both time-points, institutionally reared children showed reduced amplitudes in the P1 relative to family-reared controls. Intriguingly, a subgroup of previously institutionalized children who experienced high-quality foster-care, had P1 amplitudes which fell between those of institutionalized and family-reared age-mates. Such results seem in line with the view that ~~to reflect the influence of~~ type and/or quality of caregiving influence ~~on~~ the amplitude of this ERP component.

The cited ERP studies of face processing further ~~also~~ indicate that despite the ~~general pattern of~~ hypoactivation ~~in the case~~ of institutionalized children, their differential processing of unfamiliar and familiar faces is no different from that ~~proved identical to that~~ of the family-reared controls (Moulson et al., 2009b; Parker et al., 2005a). That is, both groups of children showed neural signs of differentiation between the two types of faces. Such results suggest that the brain functions underlying ~~such~~ facial- identity processing are generally preserved in children even when raised in a species atypical and very neglectful setting.

Neural substrates of IB in post-institutionalized children

Important to appreciate is that the evidence considered through this point illuminates average effects of institutional rearing on face processing. Given the clinical heterogeneity of children raised in institutions, it may well be problematical ~~would thus be a mistake~~ to over-generalize findings to each and every ~~the evidence to date to all~~ institutionalized child~~ren~~, even those ~~whether~~ growing up in the worst Romanian institutions ~~or such contexts elsewhere~~. We are thus led to wonder whether the variation evident in the behavioral development of institutionalized children itself reflects ~~This caution leads us to hypothesize that such heterogeneity may mask~~ consistent—and varied-- brain-behavior associations ~~stemming from institutional rearing~~. Indeed, we hypothesize ~~That is, it seems likely~~ that the separately chronicled effects of institutionalization on brain and~~, particularly,~~ on indiscriminate social behavior may apply more to some children than to others. More specifically, we predict ~~Thus, we hypothesize~~ that the face processing of institutionalized children who manifest IB differs from that of fellow institutionalized children who do not manifest IB.

To date, the neural substrates of IB have only been investigated in two studies with post-institutionalized, international adoptees, one using EEG and another using

functional Magnetic Resonance Imaging (fMRI); findings from this work provides the foundation for that presented herein. Tarullo and colleagues (2011) observed that the IB of post-institutional adoptees at 36 months was predicted by an increased concentration of spectral power in the low-frequency theta band and reduced absolute high-frequency alpha power, both measured at 18 months. These results indicate that a pattern of neural hypoactivation among children with histories of adverse early care predicts IB. In the second study Olsavsky and colleagues (2013) observed ~~reported~~ that once-institutionalized, adopted youth showed reduced amygdala differentiation in response to photographic displays of the mother's and a stranger's face, compared to family-reared controls, and that this lack of face discrimination among the adopted youth was associated with elevated IB levels.

Our team carried out the second study on the neural substrates of IB among institutionalized children, ~~More recently, our team presented preliminary findings in the first investigation on ERP correlates of behavior indicative of attachment or social engagement disturbances—in~~ using the same institutionalized Portuguese sample that is the focus of ~~assessed in~~ the current study (XXX 2015). Preliminary ERP ~~R~~results revealed, first, that institutionalized children who presented, according to the caregiver's report, atypical social behavior—(either indiscriminate or inhibited—)displayed reduced P1 amplitudes relative to similarly reared children who did not present such behavior. In a second set of analyses we extended this between-group work by carrying out a within-group comparison, comparing children who presented contrasting forms of atypical social behavior. Results revealed that it was principally the IB children, not the inhibited children, who failed to discriminate, at the neurobiological level, ~~contrasting institutionalized children displaying "opposite" presentations of atypical social behavior—indiscriminate or inhibited—an absence of signs of discrimination between~~ the face of the caregiver and that of a stranger. What remains unclear ~~occurred primarily in the subgroup of children with IB. Notwithstanding these interesting initial findings, the ERPs of these children were compared to those of institutionalized children with inhibited behavior; therefore it remains to be established~~ how such distinctive neural processing patterns of institutionalized children with IB ~~will~~ compare to those of ~~normative~~ family-reared age-mates and all other ~~to~~ institutionalized children without IB.

Current study

Thus, tThe current study aims to extend research on the face processing and social development of institutionalized children, including and extend our just-summarized initial study own previous results (XXXX 2015), by investigating two distinct sources of influence on the whether neural correlates of face familiarity: differ as a function of the rearing experience (i.e., family versus institution) and the presence/absence of IB among institutionalized children. Our approach with respect to the influence of the second factor, IB, differs from what we did in our first study. Instead of comparing only those institutionalized children showing IB and those showing inhibited behavior, we include a third group comprised of fellow institutionalized children who do not evince either atypical social-behavior pattern. This makes our ERP investigation of institutionalized children the first to distinguish all three subgroups. We further extend and refine our prior work by moving beyond a caregiver report of IB in order to evaluate whether it and an observational measure of IB prove similar in terms of their association with neural measurements. We will achieve this, by comparing indiscriminate children to fellow institutionalized children with inhibited attachment behavior and to those with no atypical socio-emotional behavior (indiscriminate or inhibited), as well as to age-mates continuously reared by their birth families. and how institutionalized children who do and do not manifest IB compare to age-mates continuously reared by their birth families.Furthermore, we will test whether analyses using an observational measure to assess IB, instead of caregiver report, obtain the same neural correlates of IB. Important to appreciate with regard to these goals is that no previous ERP investigations of institutionalized children have distinguished these subgroups. Ultimately, the design of the research reported herein affords examination of effects of both institutionalization in general and IB behavior in particular on face processing.

Three primary hypothesis derive from the On the basis of the research and reasoning considered through this point, one pertaining to the between-group contrast comparing family- and institution-reared children; a second, within-group contrast comparing three groups of institutional children; and a final one comparing all four groups of children. Because , we advance two sets of hypotheses for the current ERP study. First, Portuguese institutions also are characterized by psychosocial neglect,

~~considering that the same psychosocial neglect characteristic of the Romanian institutions (i.e., children being cared of by many rotating, often overloaded and sometimes "detached", caregivers) also characterizes the Portuguese institutions that are the subject of this report,~~ we predict, first, that institutionalized children will have ~~expect to find~~ reduced ERP amplitudes, relative to family-reared children, on ~~, on average, in~~ posterior components ~~in institutionalized Portuguese children relative to a group of children continuously reared by their birth families~~; such results would be consistent with the earlier-reported BEIP findings. We further predict that among the institutionalized children, those presenting IB will show reduced amplitudes when compared to their counterparts ~~institutionalized children~~ who do not display ~~IB~~ atypical socio-emotional behavior; this result would be in line with Tarullo et al.'s (2011) EEG findings. When it comes to the neural processing of institutionalized children showing atypical, inhibited behavior, we advance no specific hypotheses. ~~(consistent with EEG findings obtained by Tarullo et al., 2011); we have no specific hypothesis regarding the group of inhibited children.~~ Our third, primary prediction concerns face familiarity effects, with expectations also based on prior research ~~Finally~~ ~~Regarding face familiarity effects, in line with our own and others' previous findings~~ (XXX 2015; Olsavsky et al., 2013): Only institutionalized children with IB will fail to discriminate, at the neural level, the face of a stranger and that of a caregiver, not institution-reared children showing atypical, inhibited behavior or family-reared children. Our single secondary—and methodological— prediction is that hypothesis just advanced will be supported irrespective of whether IB classification is based on observation or caregiver report. ~~and consistent with the apparently equal treatment and affective~~ ~~indiscriminate~~ ~~engagement of stranger and caregiver shown by indiscriminate children, we expect to discern a lack of neural differentiation between the caregiver' and stranger's faces in the ERPs of children displaying IB, but not the remaining institutionalized children, nor the family-reared group. Finally, given convergence between measures of IB reported in the literature, we expect to find similar neural correlates of IB regardless of the measure used to assess IB.~~

Method

Participants

    Institutionalized group.

This study is part of a larger research project on the development of Portuguese institutionalized children. After approval by the Portuguese Social Services and the National Commission for Data Protection, the larger project was presented to the staff at each institution. At recruitment, participants were identified as all children aged 3-6 years old~~,~~ who had not yet entered primary school, and who did not suffer from moderate to severe mental or physical impairments, genetic syndromes or autism spectrum disorders (ASD). Written informed consent was requested from institution directors, biological parents, and participating caregivers. Of the 100 children identified as potential participants ~~at this point~~, parental consent was not obtained for 5 children. Some of the remaining 95 children were not included in the analysis sample because they ~~; 5~~ met exclusion criteria which only became evident after entry into the study ($n = $ 5; ~~related to~~ physical health problems, mental development <70 or ASD); ~~15 children~~ left the institution (for adoption or family placement) without completing the ERP assessment (n = 5); could not secure EEG recording because of child's hair ~~EEG recording~~ (n = 2); and because some children simply refused to participate in ERP recording (n = 7). ~~was impossible for 2 children because of their hair, and 7 children refused to undergo the ERP testing.~~ Of the 66 participants who underwent ERP testing, 19 had insufficient usable data due to excessive noise in the EEG or less than 20 good trials per condition.

The final sample for analysis was composed of 47 children (28 boys), who were 36–83 months old (M = 58.04, SD = 12.39) and came from ~~20~~ 19 institutions. There were 7 pairs of siblings. The majority of children (*n* = 39) were Caucasian, 4 were African-Portuguese, 2 were African, and 2 had another ethnicity. Children were admitted to the institution between 3 to 69 months of age (M = 36.28; SD = 15.51), mostly because of neglect (79%). Children had been institutionalized for 5 to 56 months (M = 21.45; SD = 14.82), and their families of origin were almost exclusively of low socioeconomic status (SES). Every child participated with their institutional caregiver, who was identified, in consultation with the institutional staff, as the child's favorite caregiver at the institution. If such a caregiver could not be so identified, the one most familiar with the child and involved in his/her daily routines served in this capacity ~~for the current research~~. In total, 37 female caregivers were enrolled in the study (i.e., 6 participated with more than one child).

These 19 institutions varied in size, housing from 8 to 46 children (M = 21, SD = 10), and employing from 4 to 53 caregivers (M = 14, SD = 11). Average ratios of children per caregiver ranged from 3 to 11 (M = 6, SD = 2). All the institutions had a specialized leadership team that included a psychologist;, and most also had a specialist in education and a dedicated social worker. All the institutions had written activity plans for children, with all such plans including a prepared plan of activities to be implemented with each age-group, and all reported to include in routines some time dedicated to play and learning. See Table 1 for sample description. participants descriptives.

Family-reared group.

A comparison group of family-reared children from the community was recruited from the local communitylocal families; Families ranged , ranging from low to medium-high sociocultural backgrounds. The same health and mental developmental exclusion criteria applied; family-reared children were also excluded if ever the focus of a child-protection measure or if ever institutionalized. , in addition to absence of any child-protection measure or history of institutionalization. Family-reared Cchildren from the in the comparison community group participated with their mothers. Of the 55 families who were contacted, 21 refused to participate, cancelled or did not attend the assessment. Families that did and did not participate did not differ in SES. One child could not be tested because of his hair. Of the 34 children who underwent ERP testing, 5 did not have sufficient usable data due to excessive noise in the EEG or had less than 20 good trials per condition. The final family-reared sample consisted of 29 children (13 boys), aged 40-75 months old (M = 57.79, SD = 10.68), all Caucasian. All except one child went to preschool. The majority of children (n = 24, 83%) lived with both biological parents, but 5 children (17%) lived with the mother and other family members (step-father or grandparents/ uncle and aunt). There were 2 pairs of siblings. Maternal educational level varied substantially: 6 (20%) went to primary school only (i.e., 4 years of education), 8 (28%) had completed 9 years of education, 7 (24%) proceeded to secondary school (i.e., 12 years of education), and the remaining 8 (28%) held a college degree. Eight mothers (28%) and three fathers (10%) were unemployed.

Identification of IB children

Measures of atypical social behavior ~~IB and inhibited behavior~~ in the institutionalized children.

~~Two measures were used to identify children who evinced IB; each is described in turn, followed by the approach for identifying indiscriminate children using the two measures.~~

The Disturbances of Attachment Interview (DAI; Smyke & Zeanah, 1999) is a semi-structured interview, administered to caregivers, addressing 12 items designed to evaluate the presence of signs of disordered attachment. For each item, the interviewer asks multiple questions (with follow-up probes) sufficient to yield a rating of 0, 1 or 2 according to the degree of evidence of disturbed or disordered attachment. To identify children with IB, we relied on questions ~~Only t~~The ~~three items~~ 6-8 pertaining to ~~addressing signs of~~ disinhibited behavior. ~~were used in the current study to identify children with IB, according to the caregiver's report~~. These items specifically address ~~concern~~ whether the child checks back with the caregiver in unfamiliar settings or tends to wander off without purpose; whether the child shows initial reticence around strangers or readily approaches unfamiliar individuals; and whether the child would readily go off with an unfamiliar adult. To identify inhibited children, we relied on questions ~~Items~~ 1-5 pertaining to ~~of the interview, addressing socio-emotional~~ withdrawal/inhibited attachment behavior~~, were used to identify inhibited children~~ (for more details about the items, see ~~cf.~~ XXXX). Whenever a child had at least one relevant question coded 2 and thus reflecting disturbed behavior being clearly present, the child was classified as IB or inhibited. ~~The cut-off for considering children to be indiscriminate was at least one the 6-8 items coded with a 2 (i.e., disturbed behavior clearly present), and the cut-off for considering children to be inhibited was at least one of the 1-5 items coded with a 2.~~ Three children met criteria for ~~eting cut-off criteria~~ for conditions and were thus excluded from the sample.~~both indiscriminate and inhibited behavior were excluded from further analyses~~[1]. Almost 80% of the interviews were rated by two independent coders (*n* = 37); discrepancies were resolved by conferencing, leading to a consensus for each item. Cohen's kappa was acceptable for the disinhibited behavior items ~~was good~~ (*M* = .75, range = .69 –.84) and for the inhibited behavior items (*M* = .63, range = .52 –.69).~~.~~

_____

[1] Ratings on Secure-Base Distortions subscales of the DAI were not considered in the current study.

The Rating of Infant and Stranger Engagement (RISE; Riley, Atlas-Corbett, & Lyons-Ruth, 2005) codes children's attachment-related forms of engagement with a ~~the~~ stranger, over all eight episodes of the Strange Situation Procedure (SSP). A small change was implemented in the administration of the SSP for preschool children (Cassidy & Marvin, 1992): regardless of the child's age, the stranger always entered the room twice, in order to provide more information for the RISE coding. Additionally, because this instrument was originally developed to assess IB in infants, its scoring was adapted to take into account the greater abilities of older children (e.g., a greater importance of verbal initiations of interaction for older children). ~~In this observational measure of IB The RISE evaluates both the extent of the child's affective engagement with the stranger compared to the caregiver, and the extent to which the child displays non-normative acceptance of physical contact or response to soothing from the stranger, resulting in a~~ Each child was rated on ~~children receive a~~ a singl~~eular~~e ~~rating on~~ a 9-point scale. Low scale scores are given to ~~represent~~ children who show a clear preference for and greater engagement with the familiar caregiver than the stranger; ~~,~~ a score of 5 indicates at least equal engagement with the stranger compared to ~~with~~ the familiar caregiver; ~~,~~ and higher scores indicate atypical ~~nonnormative~~ forms of affective engagement and attachment behavior with the stranger. A child was classified as IB if she received a score of 5 or greater. ~~According to this definition, a score of 5 or above is considered indicative of IB. Because this instrument was originally developed to assess IB in infants, an adaptation to the preschool years involved consideration of alternative demonstrations of the criteria for each score that were developmentally appropriate (e.g., a greater importance of verbal initiations of interaction for older children).~~ Inter-rater agreement based on 44 cases was very good for both the continuous scores (ICC = .94) and classifications above and below the cut-off of 5 (kappa = .82).

Scores on the DAI-disinhibited scale and the RISE were moderately correlated (*r* = .38, *p* = .01~~0~~). Notably, however, ~~, however~~ the RISE identified substantially more children as indiscriminate than did the DAI **(??% vs. ??%).** Moreover, ~~, and~~ about half the children receiving ~~more~~ extreme RISE scores of 6 or more ~~(i.e., 6-9) were below the~~ failed to qualify as IB ~~cut-off~~ on the DAI. Six of ~~Of~~ the 8 children deemed

indiscriminate on the DAI, also met IB criteria on the ~~only 2 were not so in the~~ RISE; the two that did not sstill ~~Constitution of indiscriminate and non-indiscriminate groups.~~

~~Among the institutionalized children, those who scored above the cut-off point on the RISE (i.e., a score of ≥5) *OR* the DAI-disinhibited scale (i.e., a score of 2 on at least one item) constituted the indiscriminate group. The RISE identified the same and more children as evidencing IB than did the DAI-disinhibited (*n* = 21), except for two children who were identified by the DAI-disinhibited but not by the~~ RISE ~~(yet, these children~~ had relatively high RISE scores—of ~~, namely~~ 4 and 4.5 (i.e., just below the cut-off of 5)~~)~~. ~~Thus, the final sample of 47 institutionalized children was divided in two groups: 23 children in the Indiscriminate Behavior group (IBg), and 24 in the Non-Indiscriminate Behavior group (N-IBg)—s~~See Table 1 for the distribution of participants per group.

EEG recording and ERP task

Task stimuli.

Photographs of the child's caregiver~~-- (i.e.,~~ the institutional caregiver for the institutionalized children and the mother for the family-reared children~~--)~~ and one female stranger served as stimuli. Each individual was photographed while showing ~~, posing~~ emotional expressions (i.e., happy and sad) and neutral ones. ~~expressions, were used as stimuli. However, o~~ Only the neural responses to neutral faces are the focus of ~~were analyzed for~~ the current study. The caregiver was asked to wear her hair as she usually did and, if she wore glasses, to leave them on. ~~The same single stranger's pictures were used for every child, due to practical impossibility of editing and matching the caregiver's photos beforehand.~~ The photographs were edited using *Adobe Photoshop CS5* to standardize the background, size, brightness and contrast characteristics. Photographs were resized to 217 and 180 pixels in height and width, respectively, to avoid ocular movements across the screen.

In each trial, after the face presentation, a frame appeared around it filled with either circles or stripes as a cue for a "go" or "no-go" response (counterbalanced across participants). This latter component of the task from the moment the frame appeared around the face was only used for analyses of behavioral performance. See Figure 1 for an illustration of the complete experimental paradigm, which was designed according to Todd and colleagues (Todd, Lewis, Meusel, & Zelazo, 2008). The *Presentation*

(Neurobehavioral Systems Inc) software was used to create and present this face-processing task.

Task procedure.

Children visited the laboratory with their caregiver for this assessment. The child was seated in front of the computer screen, at a distance of 100 cm, with their eyes approximately at the midpoint of the screen. A brief training procedure with other faces as stimuli was conducted prior to the task to ensure that the child understood the instructions. A researcher remained in the room monitoring and recording the child's behavior, including eye movements 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, with a total duration of 30 minutes, was divided into three 10-minutes blocks, with a few minutes interval between them (mostly for resting and recovering alertness). Recordings were conducted for the total duration of the task unless the child became too fussy, ~~too~~ sleepy, or refused to continue.

EEG recording.

The EEG was recorded with Brain Vision Recorder system using a Quickamps amplifier with 32 sintered Ag/AgCl electrodes placed at Fp1, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, C3, Cz, C4, CP5, CP1, CP2, CP6, T7, T8, TP9, TP10, P7, P3, Pz, P4, P8, PO9, PO10, O1, Oz, O2 (according to the extended 10–20 International System). The average of all electrodes was used as reference and the system was grounded with an electrode placed at AFz. Moreover, vertical and horizontal electrooculographic activity was recorded bipolarly from above and below one eye and the outer edges of the two eyes, respectively, to measure eye movements and blinks. Electrode impedances were considered acceptable if they were at or below 10 kΩ. EEG signals were continuously amplified and digitized at a rate of 250 Hz, and filtered on-line with a 0.3–70 Hz band pass filter.

EEG processing and statistical analysis.

The EEG data were analyzed with Brain Vision Analyzer software (Version 2.0.1). The EEG data were corrected for ocular artifacts (ICA; Jung et al., 2000) and digitally filtered off-line with a 0.1–30 Hz bandpass filter and notch filter (50 Hz).

Subsequently, the EEG was segmented into epochs of 1100 ms, from 100 ms pre- to 1000 ms post-stimulus after face stimuli. The data were baseline-corrected to 100 ms before face onset, and segments exceeding +/- 100 µV at any scalp electrode were rejected. Finally, corrected artifact-free trials were averaged for each subject in each condition (neutral caregiver, neutral stranger). The institutionalized children had an average of 47 good trials (range = 21–60) for the caregiver condition and 48 (range = 24–60) for the stranger condition, while the family-reared children had an average of 43 good trials (range = 25–58) for the caregiver condition and 44 (range = 27–59) for the stranger condition. Components of interest and expected respective windows for this age range were selected based on the literature and our own data. The averaged ERPs were analyzed with a semiautomatic peak detection procedure at the corresponding electrodes for each component, and all components were individually checked. When the peak was not very clear or there was, for example, a "bifid" peak, the most positive/negative peak in amplitude within the respective window was marked. Three occipital components, namely P1, N170, and P400 were detected. The P1, N170 and P400 components were identified and marked as, respectively, the largest positive peak between 80–200ms after stimuli onset, the largest negative peak between 180–360ms, and the largest positive peak between 300–500ms, at electrode sites O1 and O2 (occipital), and PO9 and PO10 (parieto-occipital).

Statistical Analysis

THIS IS VERY CONFUSING. YOUR ANALYSIS HAS TO SOMEHOW EASILY MAP ON TO THE PREDICTIONS. WASN'T THERE A FIRST PREDICTION ABOUT INSTITUTIONALIZED KIDS VS. FAMILY-REARED ONES? THEN ANOTHER COMPARING THE 3 GROUPS OF INSTITUTIONAIZED CHILDREN. AND THEN A THIRD COMPARING ALL 4 GROUPS (I.E., 3 INSTITUTIONAIZED AND 1 FAMILY-REARED)? WHAT YOU SAY BELOW DOESN'T CLEARLY MAP ON TO THIS AND WILL SURELY CONFUSE THE READER. SOMETHING MUST BE REVISED.

I THINK THE PROBLEM IS THAT YOU ARE MIXING AN MATCHING YOUR PARAMETERIZATION OF THE TWO BEHAVIOR MEASUREMENTS WITH

YOUR PRIMARY STATISTICAL ANALYSIS—TO TEST YOUR HYPOTHESES. SO MUCH OF WHAT YOU SAY BELOW SHOULD BE PART OF THE MEASURES SECTION, NOT PART OF THE STATISTICAL ANALYSIS SUBSECTION. I AM NOT GOING TO TOUCH WHAT IS BELOW BECAUSE IF IND IT TOO CONFUSING.

The statistical analysis was divided in two levels. **WHAT YOU DESCRIBE BELOW ARE NOT "LEVELS OF ANALYSIS". THEY ARE JUST SCORING OR PARAMETERIZATION RULES.**

~~that~~The first level of analysis compared the institutionalized ~~there are two institutionalized subgroups of children, the~~ Indiscriminate Behavior group (IBg) to another two subgroups of institutionalized children, the Inhibited Attachment group (IAg) and the Non-~~Indiscriminate~~ Disturbed Behavior group (N-~~IBg~~DBg; i.e., non-indiscriminate and non-inhibited), whereas the family-reared children composed a ~~third~~forth, ~~Comparison~~ Community Group (CG). These subgroups of institutionalized children were created based on DAI ratings. Given the wide age range of participants, they were also divided in two age subgroups, by a median split (Mdn = 58 months). The second level of analysis used RISE ratings to divide the institutionalized children into an Indiscriminate Behavior group (indiscriminate in the RISE, IB-Rg) and a Non-Indiscriminate Behavior group (non-indiscriminate in the RISE, N-IB-Rg), and the same family-reared group (CG) was used for comparison. The same age division was used in this second level of analysis.

For each level of analysis and for each of the ERP components, two repeated measures analyses of variance (ANOVA) with a mixed design were computed, one with peak amplitude (in µV) and the other with latency to peak (in ms) as dependent variables. Outliers were transformed with the winsorizing method. Levene's tests of homogeneity of variances and Box's tests of equality of covariance were checked. For each ANOVA the within-subjects factors were face (caregiver; stranger), region (occipital; parieto-occipital) and laterality (left; right), and the between-subjects factors were group (IBg~~.;~~ IAg, N-~~DI~~Bg ~~and;~~ CG in the 1st level; IB-Rg, N-IB-Rg and CG in the 2nd level) and age

(younger; older). Significant interactions were followed-up with post-hoc t-tests with a Bonferroni correction for multiple comparisons.

Results

Before reporting ERP findings, we present group differences in performance in the Go/No-Go task. Moving on to the ERP findings, we first report those pertaining to the first level of analysis, where institutionalized children with caregiver-rated IB are compared to institutionalized children with inhibited behavior, to institutionalized children without atypical social behavior, and to family-reared children. NOTE THAT WHAT YOU DESCRIBE IN THE PRECEEDING SENTENCE IS WHAT YOU DESCRIBED AS SECOND OR THIRD IN THE HYPOTHESIS SECTION. WHY NOT START WITH THE INSTITUTION VS. NOT INSTITUTION, THEN GO ON TO THE CMPARISON OF THE 3 INSTITUTIONAL GROUPS; AND THEN GO ON TO THE ANALYSIS THAT INCLUDES ALL 4 GROUPS. THAT SEEMS SO MUCH MORE LOGICAL. Then we report results concerning the second level of analysis, where we compare institutionalized children with IB as assessed via observation (i.e., the RISE) to institutionalized children who did not show IB on this measure, and to the family-reared group. Results for the peak and latency measures of the three ERP components are reported in turn. Findings concerning the main hypotheses outlined in the introduction are explained in more detail. See Tables 2 and 3, and Figures 2 and 3.

Behavioral performance on the Go/No-go task

To analyze group effects on children's behavioral performance on the Go/No-go task, the percentage of correct button presses (in response to Go cues) and the percentage of correct button press inhibition (in response to No-go cues) were calculated for the average of trials that each child subject completed, while controlling for participants' age. Behavioral data wereas available for 24 participants from the CG and 44 from the IG.WHAT DOES CG STAND FOR—COMMUNITY GROUP? IF YOU ARE GOING TO CALL THEM THIS, THEN ABANDON THROUGHOUT THE NOTION OF FAMILY-REARED GROUP. USING BOTH TERMS INTERCHANGABLY IS CONFUSING.

IT SEEMS TO ME THAT IN THE PRAGRAPHS BELOW YOU ARE FOLLOWING THE HYPOHTESES AS LAID OUT IN THE INTRODUCTION.

Univariate analyses revealed differences between IG and CG for accuracy in pressing the button for the Go cue, $F_{(1, 65)} = 5.42$, $p = .023$, $\eta_p^2 = .08$. Specifically, institutionalized children showed fewer correct Go responses than family-reared children.

Regarding correct performance in response to the No-go cue, there was no main effect of group, $F_{(1, 65)} = .50$, $p > .1$. Accordingly, institutionalized and family-reared children were equally accurate in inhibiting a button press.

The same analyzes with institutionalized participants divided according to their socio-emotional profile based on the DAI and on the RISE (as they are in the next two subsections of results) did not reveal any significant group effects.

First level of ERP results: How does the face processing of institutionalized children with IB compare to the other groups? I JUST DON'T GET WHY YOU START WITH THIS AND NOT WITH THE CG VS. IB ANALYSIS. I REALLY THINK YOU HAVE TO BE MUCH MORE HYPOTHESIS ORIENTED, REMINDING THE READER WHAT YOU EXPECTED. IN FACT, I CAN IMAGINE IT BEING SENSIBLE TO FOCUS EXCLUSIVELY ON WHAT YOU EXPECTED—RATHER THAN LOTS OF EXTRANEOUS "FINDINGS" AND PERHAPS COVERING THOSE IN A SUPPLEMENT OR JUST INCLUDING THEM IN A TABLE. YOU RISK LOSING THE FOREST FOR THE TREES. QUITE FRANKLY, I DO NOT SEE THE POINT IN REPORTING LOTS OF EXTRANEOUS "FINDINGS" AND RISKING MISSING THE ACTUAL TESTS OF THE HYPOTHESIS. THOSE, TO BE HONEST, SEEMED RATHER STRAIGHTFORWARD TO ME FROM THE INTRODUCTION.

P1 Component.

Peak.

There were main effects of Group, $F_{(3, 65)} = 5.75$, $p = .001$, $\eta_p^2 = .21$, and Region, $F_{(1, 65)} = 15.92$, $p < .000$, $\eta_p^2 = .20$, for peak amplitude. These were qualified by a Group x Region interaction, $F_{(3, 65)} = 3.51$, $p = .020$, $\eta_p^2 = .14$, and a Group x Face interaction, $F_{(3, 65)} = 3.26$, $p = .027$, $\eta_p^2 = .13$. Inspection of the post-hoc tests and means indicated that the group differences were significant in both parieto-occipital and occipital regions, $F_{(3, 65)} = 5.71$, $p = .002$, $\eta_p^2 = .21$ and $F_{(3, 65)} = 4.01$, $p = .011$, $\eta_p^2 = .16$ respectively, and for both the caregiver and stranger faces, $F_{(3, 65)} = 5.34$, $p = .$

002, $\eta_p^2 = .20$ and F (3, 65) = 5.57, $p = .002$, $\eta_p^2 = .20$ respectively. Overall the IBg showed significantly smaller P1 amplitudes than the CG and than the N-DBg (Mean difference = -7.48 and -7.25, respectively); the IBg did not differ from the IAg (Mean difference = -2.69). However, the IAg had significantly smaller amplitudes than the CG (Mean difference = -4.78). *In summary, institutionalized indiscriminate children showed smaller P1 amplitudes than fellow institutionalized children without disturbed behavior, and smaller than family-reared children. Institutionalized children with inhibited attachment behavior had intermediate amplitudes between the indiscriminate children and the other two groups.*

There were also main effects of Hemisphere, F (1, 65) = 5.17, $p = .026$, $\eta_p^2 = .07$, and Age, F (1, 65) = 4.30, $p = .042$, $\eta_p^2 = .06$, indicating that the P1 was larger over the right than left hemisphere, and larger among older than younger participants.

Latency.

There were no significant results for P1 latency.

N170 Component.

Peak.

There was a main effect of Region, F (1, 65) = 12.65, $p = .001$, $\eta_p^2 = .16$, which qualified by a Face x Region interaction, F (1, 65) = 11.91, $p = .001$, $\eta_p^2 = .16$. Inspection of the post-hoc tests and means indicated that over the parieto-occipital electrodes, participants showed larger N170 amplitudes in response to the caregiver than the stranger's face (Mean difference = -1.54), F (1, 65) = 5.89, $p = .018$, $\eta_p^2 = .08$ (but not over occipital electrodes, F (1, 65) = .28, $p > .1$).

There was also a Group x Face interaction, F (3, 65) = 4.04, $p = .011$, $\eta_p^2 = .16$. Inspection of the post-hoc tests and means indicated that both the CG and the IAg showed a larger N170 in response to the caregiver than the stranger's face (Mean difference = -2.10 and -2.65, respectively), F (1, 65) = 11.32, $p = .001$, $\eta_p^2 = .15$ and F (1, 65) = 6.95, $p = .010$, $\eta_p^2 = .10$, respectively. In contrast, the IBg and the N-DBg did not show significantly different amplitudes between the two faces (Mean difference = 2.35 and -.15, respectively), F (1, 65) = 2.38, $p > .1$ and F (1, 65) = .05, $p > .1$, respectively. *In summary, only family-reared and institutionalized children with inhibited attachment*

behavior showed face familiarity discrimination in N170 amplitudes, namely larger for the caregiver than the stranger (see Figure 2).

Latency.

There were main effects of Group, $F(3, 65) = 5.43$, $p = .002$, $\eta_p^2 = .20$, Age, $F(1, 65) = 9.77$, $p = .003$, $\eta_p^2 = .13$, and Region, $F(1, 65) = 7.69$, $p = .007$, $\eta_p^2 = .11$. These were qualified by a Group x Age, $F(3, 65) = 3.27$, $p = .027$, $\eta_p^2 = .13$, a Group x Age x Face, $F(3, 65) = 4.03$, $p = .011$, $\eta_p^2 = .16$, and a Group x Age x Face x Region, $F(3, 65) = 3.30$, $p = .026$, $\eta_p^2 = .13$ interactions. Inspection of the post-hoc tests and means indicated that in both regions and for both faces, group differences were seen among younger participants, namely longer N170 latencies by the IAg and the NDBg than the CG (all $p < .05$); there were no differences among older participants or between the IBg and the remaining groups (all $p > .1$).

P400 Component.

Peak.

There were main effects of Group, $F(3, 65) = 2.75$, $p = .050$, $\eta_p^2 = .11$, Age, $F(1, 65) = 10.30$, $p = .002$, $\eta_p^2 = .14$, and Region, $F(1, 65) = 21.40$, $p < .000$, $\eta_p^2 = .25$. These indicated that the P400 was smaller in the IBg than the CG (Mean difference = -4.16), smaller in younger than older participants (Mean difference = -2.99), and smaller in occipital than parieto-occipital electrodes (Mean difference = -2.58). These main effects were qualified by an Age x Face x Region x Hemisphere interaction, $F(1, 65) = 7.61$, $p = .008$, $\eta_p^2 = .11$, and a Group x Age x Face x Region x Hemisphere interaction, $F(3, 65) = 4.03$, $p = .011$, $\eta_p^2 = .16$, but specific subgroup differences were not detectable on follow-up. *In summary, institutionalized indiscriminate children showed smaller P400 amplitudes than family-reared age-mates. Non-disturbed institutionalized children showed amplitudes that were very close to those of family-reared age-mates and were no different from any other group. Inhibited children showed amplitudes that fell between those two groups and the group of indiscriminate children, but not significantly different from any other group.*

Latency.

There were a Group x Hemisphere, $F (3, 65) = 2.82$, $p = .046$, $\eta_p^2 = .16$, and a Group x Face x Hemisphere, $F (3, 65) = 3.96$, $p = .012$, $\eta_p^2 = .15$, interactions, but specific subgroup differences were not detectable on follow-up.

There were also an Age x Hemisphere, $F (1, 65) = 5.00$, $p = .029$, $\eta_p^2 = .07$, a Face x Hemisphere, $F (1, 65) = 4.17$, $p = .045$, $\eta_p^2 = .06$, and an Age x Face x Hemisphere, $F (1, 65) = 8.03$, $p = .006$, $\eta_p^2 = .11$, interactions. Inspection of the post-hoc tests and means indicated that for the stranger's face but only over the right hemisphere, older participants showed faster latencies than younger ones (Mean difference = 32.69).

Second level of ERP results: What are the neural correlates of face processing in institutionalized children with observer-rated IB?

P1 Component.

Peak.

There was a main effect of Region, $F (1, 69) = 35.49$, $p < .000$, $\eta_p^2 = .34$, for peak amplitude, which was qualified by a Group x Region interaction, $F (2, 69) = 3.75$, $p = .028$, $\eta_p^2 = .10$. Inspection of the post-hoc tests and means indicated that in parieto-occipital electrodes, both the IB-Rg and the N-IB-Rg showed significantly smaller P1 amplitudes than the CG (Mean difference = -4.90 and -4.45, respectively), $F (2, 69) = 4.32$, $p = .017$, $\eta_p^2 = .11$ (but not in occipital electrodes, $F (2,69) = .26$, $p > .1$). *In summary, over the parieto-occipital region, institutionalized children with or without observer-rated IB showed smaller P1 amplitudes than family-reared children.*

There was also a main effect of Hemisphere, $F (1, 69) = 12.93$, $p = .001$, $\eta_p^2 = .16$, indicating that for all participants the P1 was larger over the right than left hemisphere. ~~There was a main effect of Region for peak amplitude, $F (1, 70) = 35.36$, $p < .000$, $\eta_p^2 = .34$, which was qualified by a Group x Region interaction, $F (2, 70) = 3.96$, $p = .024$, $\eta_p^2 = .10$. Inspection of the post-hoc tests and means indicated that in parieto-occipital electrodes the CG showed significantly larger P1 amplitudes than the IBg, $F(2,70) = 4.52$, $p = .014$, $\eta_p^2 = .11$ (but not in occipital electrodes, $F (2,70) = .29$, $p > .1$); the N-IBg was intermediate but not significantly different from either group. More specifically, the mean difference between CG and IBg was 5.09 ($p = .021$), between CG and N-IBg it was 4.11 ($p = .084$), and between N-IBg and IBg it was .98 ($p > .1$). In~~

summary, over the parieto-occipital region, institutionalized indiscriminate children showed smaller P1 amplitudes than family-reared children; non-indiscriminate institutionalized children had intermediate amplitudes between the other two groups.

There was also a main effect of Hemisphere, F (1, 70) = 14.43, p < .000, η_p^2 = .17, indicating that for all participants the P1 was larger over the right than left hemisphere.

Latency.

~~There was a main effect~~ There was a main effect of Region, F (1, 69) = 66.18, p < .000, η_p^2 = .49, indicating that latencies to the P1 were faster in occipital than parieto-occipital electrodes.

There was also an Age x Face interaction, F (1, 69) = 4.80, p = .032, η_p^2 = .07. Inspection of the post-hoc tests and means indicated that older participants showed a faster N170 latency to the caregiver's than the stranger's face (Mean difference = -5.39), F (1, 69) = 5.66, p = .020, η_p^2 = .08 (but not younger participants, F (1, 69) = .48, p > . 1). ~~of Region for latency to peak, F (1, 70) = 75.63, p < .000, η_p^2 = .52, indicating that the P1 was faster over occipital than parieto-occipital electrodes.~~

~~There was also an Age x Face interaction, F (1, 70) = 4.90, p = .030, η_p^2 = .07, which was qualified by a Group x Age x Face x Hemisphere, F (2, 70) = 3.66, p = .031, η_p^2 = .10; follow-up analyses failed to detect subgroup differences, however.~~

N170 Component.

Peak.

There were main effects of Age, F (1, 69) = 4.10, p = .047, η_p^2 = .06, and Region, F (1, 69) = 29.06, p < .000, η_p^2 = .30, which were qualified by a Group x Region, F (2, 69) = 3.20, p = .047, η_p^2 = .09, and a Group x Age x Region interaction, F (2, 69) = 3.23, p = .046, η_p^2 = .09, interactions. However, specific subgroup differences were not detectable on follow-up.

There was also a main effect of Face, F (1, 69) = 9.30, p = .003, η_p^2 = .12, which was qualified by a Face x Region interaction, F (1, 69) = 17.59, p < .000, η_p^2 = .20. Inspection of the post-hoc tests and means indicated that in parieto-occipital electrodes the N170 was larger in response to the caregiver's than the stranger's face (Mean difference = -2.10), F (1, 69) = 17.67, p < .000, η_p^2 = .20 (but not on occipital ones, F (1,

69) = .96, $p > .1$). *In summary, when using the observational measure to rate IB, all participants showed face familiarity discrimination in N170 amplitudes.*

Finally, there was a main effect of Hemisphere, $F(1, 69) = 3.99$, $p = .050$, $\eta_p^2 = .06$, indicating that the N170 was larger over the left than right hemisphere. ~~There were main effects of Age, $F(1, 70) = 3.97$, $p = .050$, $\eta_p^2 = .05$, and Region, $F(1, 70) = 34.67$, $p < .000$, $\eta_p^2 = .33$, which were qualified by a Group x Region interaction, $F(2, 70) = 3.25$, $p = .045$, $\eta_p^2 = .09$, and by a Group x Age x Region interaction, $F(2, 70) = 3.44$, $p = .038$, $\eta_p^2 = .09$. Inspection of the post-hoc tests and means indicated that among older children and over the parieto-occipital electrodes, the CG showed larger N170 amplitudes than the IBg, $F(2,70) = 3.13$, $p = .050$, $\eta_p^2 = .08$ (but not among younger children or in occipital electrodes, all $p > .1$); the N-IBg was intermediate but not significantly different from either group. More specifically, the mean difference between CG and IBg was -5.73 ($p = .046$), between CG and N-IBg it was -3.02 ($p > .1$), and between N-IBg and IBg it was -2.71 ($p > .1$). In summary, over the parieto-occipital region and among older participants, institutionalized indiscriminate children showed smaller N170 amplitudes than family-reared children, with non-indiscriminate institutionalized children evidencing intermediate amplitudes between the other two groups.~~

~~There was also a main effect of Face, $F(1, 70) = 9.40$, $p = .003$, $\eta_p^2 = .12$, which was qualified by a Face x Region interaction, $F(1, 70) = 20.86$, $p < .000$, $\eta_p^2 = .23$. Inspection of the post-hoc tests and means indicated that, regardless of group, the N170 was larger in response to the caregiver's than the stranger's face in parieto-occipital electrodes, $F(1, 70) = 19.82$, $p < .000$, $\eta_p^2 = .22$ (but not on occipital ones, $F(1, 70) = .55$, $p > .1$). More specifically, the mean difference between the caregiver' and stranger's face in the former region was -2.14 ($p < .000$). In summary, all participants showed face familiarity discrimination in N170 amplitudes.~~

Latency.

For latency to peak, there were main effects of Group, $F(2, 70) = 4.03$, $p = .022$, $\eta_p^2 = .10$, Age, $F(1, 70) = 9.27$, $p = .003$, $\eta_p^2 = .12$, and Region, $F(1, 70) = 18.36$, $p < .000$, $\eta_p^2 = .21$. First, children in the CG showed faster latencies to the N170 than the N-IBg (mean difference of -14.78, $p = .019$); however there were no significant differences between the CG and the IBg (mean difference of -7.89, $p > .1$) or between the IBg and

~~the N-IBg (mean difference of -6.90, $p > .1$). Second, regardless of group, older children showed faster latencies than younger ones. Lastly, the N170 was faster over occipital than parieto-occipital electrodes.~~

For latency to peak, there were main effects of Group, F (2, 69) = 4.05, $p = .022$, $\eta_p^2 = .11$, and Age, F (1, 69) = 9.11, $p = .004$, $\eta_p^2 = .12$, which were qualified by a Group x Age x Face, F (2, 69) = 4.37, $p = .016$ $\eta_p^2 = .11$ interaction. Inspection of the post-hoc tests and means indicated that there were group differences among younger participants and for both caregiver and stranger faces, F (2, 69) = 7.18, $p = .001$ $\eta_p^2 = .17$ and F (2, 69) = 4.45, $p = .015$ $\eta_p^2 = .11$ (but not among older participants, all $p > .1$). Specifically, both the IB-Rg and the N-IB-Rg had slower latencies than the CG for the caregiver's face (Mean difference = 21.81 and 25.41, respectively), while for the stranger's face only the IB-Rg had slower latencies than the CG (Mean difference = 21.85).

There was also a main effect of Region, F (1, 69) = 15.05, $p < .000$, $\eta_p^2 = .18$, indicating that latencies to the N170 were faster in occipital than parieto-occipital electrodes.

P400 Component.

Peak.

There were main effects of Age, F (1, 69) = 8.10, $p = .006$, $\eta_p^2 = .11$, and Region, F (1, 69) = 41.00, $p < .000$, $\eta_p^2 = .37$. These main effects were qualified by an Age x Region x Hemisphere interaction, F (1, 69) = 6.78, $p = .011$, $\eta_p^2 = .09$, and a Group x Age x Face x Region x Hemisphere interaction, F (2, 69) = 4.43, $p = .016$, $\eta_p^2 = .11$. Despite these interactions, specific subgroup differences were not detectable on follow-up. ~~There were main effects of Age, F (1, 70) = 8.04, $p = .006$, $\eta_p^2 = .10$, and Region, F (1, 70) = 41.47, $p < .000$, $\eta_p^2 = .37$, indicating that the P400 was larger in older than younger participants, and larger in parieto-occipital than occipital electrodes. These main effects were qualified by an Age x Region x Hemisphere interaction, F (1, 70) = 6.59, $p = .012$, $\eta_p^2 = .09$, an Age x Face x Region x Hemisphere interaction, F (1, 70) = 4.82, $p = .031$, $\eta_p^2 = .06$, and a Group x Age x Face x Region x Hemisphere interaction, F (2, 70) = 3.79, $p = .027$, $\eta_p^2 = .10$. Despite these interactions, specific subgroup differences were not detectable on follow-up.~~

Latency.

There was a main effect of Region, F (1, 69) = 10.57, p = .002, η_p^2 = .13, indicating that latencies to the P400 were faster in occipital than parieto-occipital electrodes.

There was also a Group x Age x Face interaction, F (2, 69) = 3.75, p = .028, η_p^2 = .10, however specific subgroup differences were not detectable on follow-up.

Subsequently we re-run all analyses from the Second level excluding children who were rated as showing inhibited attachment (on the DAI)—some were part of the IB-Rg and some were from the N-IB-Rg. There is one main finding that changes. Specifically, the group differences in P1 amplitude become non-significant. was a main effect of Region for latency to peak, F (1, 70) = 9.20, p = .003, η_p^2 = .12, indicating that the P400 was faster over occipital than parieto-occipital electrodes.

There was also a Group x Age x Face interaction, F (2, 70) = 3.70, p = .030, η_p^2 = .10, but, once again, specific subgroup differences were not detectable on follow-up.

Discussion

The aim of this study was to investigate the neural correlates of face familiarity processing and their association with displays of indiscriminate social behavior (IB) in the context of exposure to institutionalization. More specifically, we sought to extend our previous findings (XXX 2015) to determine whether displays of IB in part explain differences in neural activation patterns in face processing among institutionalized and between such children and their family-reared counterparts. Toward this end—in the first level of analysis—, the ERPs of institutionalized children who presented IB, —according to their caregiver's report and laboratory observations, —were compared to institutionalized children who did not present IBatypical social behavior, and to family-reared age-mates. In order to account for the confound of inhibited attachment behavior, inhibited-institutionalized children constituted another comparison group, and children with comorbidity between indiscriminate and inhibited behavior were excluded from analyses. A second aim of the study—and second level of analysis—was to analyze the neural correlates of face processing among institutionalized children with and without IB when this behavior was assessed via laboratory observations, to test the replicability of caregiver report findings.

The ERPs of th~~ese~~e ~~three~~ different groups of children in response to photographs of their caregiver's face and to that of a stranger were analyzed in terms of components' amplitude and latency, signs of differentiation between the two faces and regional/laterality effects. We now discuss the more relevant findings—which address our specific hypotheses—concerning group differences in magnitude of ERP peak amplitudes and, thereafter, those pertaining to effects of face familiarity. We will give more focus to results obtained in the first level of analysis, where institutionalized children's socio-emotional behavior was categorized as indiscriminate, inhibited, or not-disturbed (according to caregiver's report), but comment on changes to results obtained in the second level of analysis, where appropriate.

Group differences in magnitude of ERP amplitudes

Recall that the first set of hypotheses stipulated (a) that institutionalized children, as a ~~whole~~group, would show blunted ERP posterior components in comparison to children continuously reared by their birth families, and (b) that such reduction in ERP amplitudes would be particularly pronounced among those institutionalized children presenting IB, reflecting a pattern of hypoarousal. Consistent with these predictions, results revealed that institutionalized children with IB had smaller P1 and P400 peak amplitudes than family-reared comparison children (specifically, about half the amplitude), with institutionalized children with~~out IB~~ inhibited behavior showing intermediate amplitudes falling between ~~the~~ those other two groups, and institutionalized children without indiscriminate or inhibited behavior showing amplitudes close to those of family-reared children. ~~More specifically, IB children showed a smaller P1 than the family-reared group, and a smaller N170, but the latter only in the case of older participants. Important to appreciate, however, is that these effects were only significant over the parieto-occipital leads, where these two components were maximal. Institutionalized children without IB exhibited intermediate P1 and N170 amplitudes that were not significantly different from either group. The group differences in the P400 failed to reach statistical significance, but the means suggested, nevertheless, that the IB children had smaller peak amplitudes than the other two groups.~~

~~Considered together, t~~These findings suggest that the previously reported hypoactivation in institutionalized children, on average (Moulson et al., 2009a; Moulson

et al., 2009b; Parker et al., 2005a, 2005b), is most characteristic of those who have developed this atypical profile of engagement with adults. IB, characterized by an indiscriminate approach of strangers, is one of the most frequent and persistent effects of early institutional rearing, associated with long-term impairments in social development (Hodges & Tizard, 1989; Kreppner et al., 2010). Therefore, it may not be entirely surprising that such behavioral sequela of institutionalization also manifests itself at the neural level. Unfortunately, it is not possible, given the design of the current study, to make inferences about causation, given that institutionalization is associated with both IB and neural hypoactivation and they cannot be teased apart from a temporal-order perspective herein. In the remainder of this subsection, we move beyond the broad conclusions just advanced to consider results for each ERP component separately.

The P1 component.

Starting with the P1, even though it is a component that does not show sensitivity to facial identity in adults or typically developing children (Caharel et al., 2007; Caharel, Courtay, Bernard, Lalonde, & Rebaï, 2005; Todd et al., 2008), given that it corresponds to a very early sensory response, it is influenced by selective attention (Hillyard & Anllo-Vento, 1998). Therefore, the reduced peak amplitude among the institutionalized children, particularly those with IB, could reflect some kind of (e.g., attentional) deficit at the sensory stage of visual perception of faces; however, given that institutionalized children's reduced amplitudes—both in ours and others' studies—continue throughout the entire ERP epoch, a more generalized deficit in face processing is more likely.suggests deficits at the sensory stage of visual perception of faces or in selective attention (Caharel et al., 2007).

Our results are in agreement with those chronicled in the BEIP sample at baseline, 30- and 42-months assessments; specifically, in this work institutionalized children showed a smaller P1 than those in the never-institutionalized group, with children randomized to foster-care evidencing intermediate P1 amplitudes between these other two groups (Moulson et al., 2009a; Moulson et al., 2009b). The current work extends such literature, as well as our own previous report of within-group comparisons (XXX 2015), in showing that the reductions in P1 amplitudeo be noted, however, is that differences betweenamong the institutionalized children, when compared and to the

family-reared group, was attributable to the two groups of children with symptoms of socio-emotional disturbance, that is, the indiscriminate and the inhibited groups. Moreover, indiscriminate children had particularly low P1 amplitudes, which were also significantly smaller than the non-disturbed institutionalized group.

Please note that while our second level of analysis would suggest that all IG children show a blunted P1, it was the distinction of indiscriminate, inhibited and non-disturbed groups (in the first level of analysis, based on caregiver-rated behaviors) that allowed us to disentangle such findings. Specifically, the reduced P1 amplitude of institutionalized children seem to have been a function of the existence of socio-emotional disturbances, and primarily the manifestation of IB rather than inhibition. To our way of thinking, this is an important insight, helping to account for heterogeneity in the behavioral and neural responses of institutionalized children.

s in P1 amplitude were more dramatic in the BEIP sample, at least for the stranger's condition, than in the current study. The smaller group difference in our sample of Portuguese institutionalized children reflects perhaps the fact that most children in the current study were institutionalized at a later age than their BEIP counterparts (i.e., after 6 months of age, except for two cases) and/or that they were placed in better-quality institutions.

The P1 results lead us to reframe the findings of our previous report with this sample of institutionalized children. Recall that in that first study we observed that the presence of (any) atypical social behavior—IB or inhibited attachment—was associated with a smaller P1 while processing faces (XXX 2015). Based on the current findings, however, we conclude that this sample of Portuguese institutionalized children overall show a blunted P1 while processing faces (i.e., in comparison to a normative group of family-reared children), but also that the initial results seem to have been a function primarily of the children manifesting IB rather than inhibition. To our way of thinking, this is an important insight, helping to account for heterogeneity in the behavioral and neural responses of institutionalized children.

The N170 component.

The second set of findings compatible with hypoactivation was that IB children showed a significantly smaller N170 peak than did family-reared children, with their non-

IB institutionalized age-mates falling between these other two groups (even if not proving significantly different from either), at least in the case of older participants. These results differ from those of the BEIP, where a reduced N170 amplitude was found at the baseline assessment of the institutionalized children relative to their family-reared counterparts (when children were 6-30 months old; Parker et al., 2005a; Parker, Nelson, & The BEIP Core Group, 2007), but was not evident at subsequent follow-ups with either the face-familiarity or the emotional-expressions tasks (Moulson et al., 2009b; Nelson, Westerlund, McDermott, Zeanah, & Fox, 2013). Such cross-study inconsistency might be explained by the fact that the current study included a wider age range than did the BEIP, with the effects under consideration being detected in the older children. Such an analysis would seem consistent with evidence that the N170, a marker for the structural encoding and configural processing of faces (Caharel et al., 2007; Eimer, 2011), changes significantly throughout development (Kuefner, de Heering, Jacques, Palmero-Soler, & Rossion, 2010; Taylor, Batty, & Itier, 2004). Future studies seeking to clarify this issue should repeatedly measure the N170 in institutionalized and family-reared children as they develop.

The P400 component.

InRegarding the current research there were no significant group differences in P400 amplitudes, similarly to what was seen for the P1, even though the ranking of group means (see Fig. 2 and Table 2) indicated that IBindiscriminate children showed smaller P400 amplitudes than family-reared age-mates; inhibited children showed amplitudes that were in between those two groups, and not significantly different from either, while institutionalized children without disturbed behaviors had similar amplitudes to that of the family-reared group, but no different from any group.had smaller amplitudes than did children in the two other groups. Conceivably, chronological age-differences in P400—which proved significant in this sample—obscured group differences. Before embracing this possibility, it must be acknowledged that the BEIP also failed to detect differences between institutionalized and family-reared children in P400 amplitude during the face-familiarity task (Moulson et al., 2009b). Despite real risks in embracing (even replicated) null findings, results of both studies suggest that the hypoactivation discerned in institutionalized children (as a whole) in the early stages of face processing—at least in

~~abilities involved in the processing of face identity—fades somewhat in the later ERP epoch. In future work, a re-evaluation of this issue with a larger institutionalized sample could help determine whether that attenuation of hypoactivation in the later stage of processing does or does not apply specifically to institutionalized children with IB.~~ The P400 is a component that demonstrates face sensitivity, likely corresponding to a precursor of the N170 (de Haan, Johnson, & Halit, 2007), which, in turn, is a component reflecting the structural encoding of faces (Eimer, 2011; Kuefner, de Heering, Jacques, Palmero-Soler, & Rossion, 2010). In the BEIP, while group differences were not significant during the face recognition task (Moulson et al., 2009b), during the emotion expressions task institutionalized children did show a smaller P400 than never-institutionalized children at 42 months—with children randomized to foster care showing intermediate amplitudes between the other two groups (Moulson et al., 2009a). Together, these findings indicate that children reared in institutions show a blunted P400 but that, again, such effect of institutional rearing seems to be mostly a function of the presence of IB.

Even though inhibited children's P400 amplitude was in between that of indiscriminate and that of family-reared children, it wasn't significantly different from the latter (contrary to what happened for the P1 component). That suggests that the P400 might be a particularly good marker to distinguish the neural correlates associated specifically with IB (as it is assessed in the DAI), and not other socio-emotional disturbances. Consistent with that hypothesis, when institutionalized children were divided in two groups based on the RISE (in the second level of analysis) no group differences were detected for P400 amplitudes—even though the averages were in the same direction of those in the first level of analysis. Because the RISE assesses IB in a different and less stringent way, as we will see later in this discussion, it might capture other types of behavior that obscure the association between P400 amplitude and IB.

Overall, then, the findings of the current study are in line with much prior research in showing that institutionalized children evince reduced amplitudes in occipital components when processing faces, in comparison to family-reared children. Moreover, the results of this inquiry prove largely consistent with the prediction that the presence of IB contributes to explain variability in this effect among institutionally reared children.

The reductions in amplitudes shown by institutionalized children while perceiving faces have been interpreted as evidence of cortical hypoarousal (Moulson et al., 2009a; Moulson et al., 2009b; Parker et al., 2005a). While there are indications in the literature on EEG spectral power that such hypoactivation might not be exclusive to face processing (Marshall et al., 2004; Tarullo et al., 2011; Vanderwert et al., 2010), it is likely that the networks involved in face processing are particularly affected by institutional rearing (Moulson et al., 2009b). This would be consistent with behavioral data indicating that the socio-emotional domain is particularly susceptible to effects of institutional rearing, often with quite persistent effects (Bakermans-Kranenburg et al., 2011). The finding of neural correlates associated with IB is also consistent with the idea of experience-dependent programming advanced in the introduction, as an explanation of the frequent persistence of IB well into the post-institutional period.

Concurrently, it is also plausible that difficulties in the ability to orient or sustain attention, among the institutionalized children and particularly for those with IB, are at least partly responsible for the hypoarousal detected herein. Research on institutionalized children, which reveals both neural markers of lack of attention/response monitoring, and behavioral inaccuracy in performing a required response, highlights this as a major difficulty in these children (Loman et al., 2013; McDermott, Westerlund, Zeanah, Nelson, & Fox, 2012). Consistent with the two studies just cited, the behavioral performance of institutionalized children in the current study (i.e., error of omission of a response in Go trials, but accuracy in inhibiting a response in No-go trials) reflects difficulties in sustained attention, rather than selective attention or inhibitory control. However, we did not detect differences according to children's displays of IB. This could have been due to lack of statistical power or to the existence of other mechanisms in the explanation of the neural hypoactivation among children with IB. Nevertheless, this question deserves to be explored further in future studies given IB children's putative problems with inhibitory control.

Effects of face familiarity

We now turn to discuss differences between groups regarding the differential processing of the caregiver' and the stranger's faces. Our hypothesis that the IB children, in contrast to their fellow institutionalized, but non-disturbed counterparts, would fail

to show discrimination between the two faces, did not receive support. Indeed, only family-reared and institutionalized children with inhibited attachment behavior showed face familiarity discrimination in N170 amplitudes, namely larger for the caregiver than the stranger. It is unclear why inhibited children showed the same pattern of identity discrimination than family-reared children, but fellow institutionalized children without disturbed behavior did not. Nevertheless, it is informative that with participants divided in such groups (as they were in the first level of analysis), not only the latter group but also indiscriminate children failed to show significantly different N170 amplitudes in response to each face type. In contrast, when institutionalized children's division was based on the RISE (in the second level of analysis) and compared to the family-reared group, there was a main effect of face familiarity in N170 amplitudes—which would seem to support previous literature suggesting that institutionalized children, as a whole, discriminate familiar from unfamiliar faces similarly to controls. However, our results show that when we take into account not only indiscriminate but also inhibited behavior (according to DAI ratings) this is not the case.

It is intriguing—even though we need to be cautious due to lack of statistical significance and small number of caregiver-rated IB children—that the pattern of average amplitudes shown by indiscriminate children in response to each face type appeared to be the reverse of that shown by family and inhibited children (i.e., stranger > caregiver in IB children). Future research with a larger sample of IB children would help clarify if they do not differentiate the two faces or if their pattern of differentiation is atypical.

It is also necessary to consider that even though we included a family-reared group whose ERP patterns could be considered normative for purpose of comparison to institutionalized children, ~~regardless of group, our participants showed face discrimination in their neural responses, namely a larger N170 in response to the caregiver's face when compared to the stranger's. Nevertheless, inspection of the means indicates that it was mainly the family-reared group who demonstrated this discrimination of faces, while IB children showed very identical amplitudes to both faces.~~ the familiarity processing pattern that we found ~~As it turns out,~~ (i.e., larger N170 for familiar than unfamiliar faces) ~~our results are~~ is inconsistent with ~~those~~ results emerging from related studies, which are themselves not entirely consistent with each

other (Caharel et al., 2002; Gunji, Inagaki, Inoue, Takeshima, & Kaga, 2009; Moulson et al., 2009b; Todd et al., 2008).

In order to interpret these inconsistencies it is important to take into account that although the N170 has generally been considered to index the structural encoding of physical information in faces (Caharel et al., 2007; Kuefner et al., 2010), its role in identity processing is not as well established (Caharel et al., 2002; de Haan et al., 2007; Eimer, 2011; Taylor, Batty, & Itier, 2004). The inconsistencies in findings, then, might also result from developmental changes in face processing in general, and in changes in the N170 in particular (Taylor et al., 2004; Taylor, McCarthy, Saliba, & Degiovanni, 1999). Also, a limitation that needs to be recognized in the current study is the presentation of photographs of a single stranger, who was not matched to each caregiver's face, potentially creating a confound in familiarity effects that are influenced by configural characteristics of faces. Future research focused on the sensitivity of the N170 to face familiarity/identity throughout development is warranted to clarify these inconsistencies.

Observer versus caregiver ratings of IB

One of the aims of this study was to analyze whether assessing IB based on laboratory observations, with the RISE, introduced changes to findings obtained with caregiver-reported IB (on the DAI). The RISE is a measure that is substantially different from the DAI, and less frequently used in the literature of attachment disturbances. Given the way the RISE conceptualizes and looks for evidence of IB, relying heavily on the balance between the child's behavior directed toward the caregiver versus behavior directed toward the stranger, it also captures lack of selectivity in the child's attachment to the caregiver. There is increasing consensus in current understanding of IB that displays of IB toward strangers do not preclude the existence of selective attachments toward caregivers (Zeanah & Gleason, 2015)—and this way of thinking is reflected on the DAI items. This difference in rationale behind each of these measures has fundamental implications to what is considered as evidence of IB, resulting in different children (however significantly overlapping) being classified as indiscriminate. Also, given that the RISE captures such lack of selectivity between the two adults present in the Strange Situation, which is so frequent in institutionalized samples, it is not surprising

that it identifies more "positive cases" than the DAI. In turn, the DAI is a report measure, and as such subjected to bias, but more importantly in institutionalized samples, in relies in information provided by caregivers who often do not know well the children they look after. Nevertheless, in the presence of insufficient information, interview ratings will likely underestimate rather than overestimate children's displays of IB. Considering that both these measures have each their own strengths and limitations, we decided to include both in the current study. However, results of children's neural correlates of face processing that depend on their specific socio-emotional profiles became clearer when we used the groups distinctions created by the DAI, which not only allowed to differentiate types of behavior but also appeared to have more stringent cut-off criteria for IB.

Summary and future directions

The current work investigated the neural correlates of face familiarity among a group of Portuguese currently institutionalized preschoolers, contributing to illuminate both average effects of institutional rearing and variability among such children, particularly that accounted for by the presence of IBwith and without IB. The study provides evidence that displays of IB, a frequent behavioral outcome of early institutionalization, moderates is associated with particularly accentuated neural hypoactivation in institutionalized children's neural hypoactivation when processing faces. These findings add to growing evidence of the deleterious effects of adverse early care, specifically institutional rearing, on neurodevelopment (Belsky & de Haan, 2011; Bilson, 2009). Crucially, our data show that the neural hypoactivation described in previous studies with children placed in Romanian orphanages in the early 2000s generalize to a very different context of institutional care, given that children in this sample were older at admission (i.e., > 6 months-old in all except 2 cases) and were living in generally good-quality institutions. Finally, our findings suggest that, contrary to previously existing evidence, not all institutionalized children show equal face familiarity processing.

Future research on the neurodevelopmental effects of institutional rearing should take into account children's variability in socio-emotional profiles.

Future work should assess children's inhibited attachment behavior using observational measures in order to illuminate which effects of institutionalization on neurodevelopment are modulated by the presence of disturbances in social engagement in general and which are specific to indiscriminate behavior—and which characterize all or most institutionalized children after taking into account the presence of these disturbed behaviors. In addition, given that genetic variability and prenatal risk are associated with both neurodevelopment (de Geus, 2010; Fox, Levitt, & Nelson, 2010) and with worse behavioral outcomes in institutionalized children (Nelson, 2007), future work would benefit from taking these factors into account.

Table 1. Participants' descriptive statistics.

		Gender	Age M (SD)	DQ M (SD)	Age at admission M (SD)	% life in institution M (SD)
CG (*n* = 29)		13 M; 16 F	57.45 (10.36)	111.01 (10.93)	--	--
IG (*n* = 47)		28 M; 19 F	58.04 (12.39)	98.02 (9.89)	36.28 (15.51)	36.61 (23.68)
DAI	IBg	2 M; 3 F	64.80 (10.52)	96.06 (6.38)	37.20 (17.05)	42.34 (27.89)
DAI	IAg	10 M; 3 F	60.15 (12.83)	98.24 (9.67)	39.15 (17.63)	33.57 (23.67)
DAI	N-DBg	16 M; 10 F	56.62 (12.12)	98.29 (9.82)	34.46 (15.25)	38.72 (24.20)
RISE	IB-Rg	11 M; 9 F	54.15 (13.68)	100.07 (9.70)	37.20 (16.04)	32.01 (20.66)
RISE	N-IB-Rg	16 M; 10 F	60.27 (10.34)	96.45 (10.13)	35.92 (15.58)	39.04 (25.51)

	~~CG (*n* = 29)~~ M (SD)	~~IBg (*n* = 23)~~ M (SD)
~~Gender~~	~~13 male; 16 female~~	~~12 male; 11 female~~
~~Age~~	~~57.79 (10.68)~~	~~55.78 (13.83)~~
~~Developmental quotient~~	~~111.01 (10.93)~~	~~99.11 (9.47)~~

Note. CG = ~~Comparison~~ Community group; IG = Institutionalized Group; DAI = Disturbances of Attachment Interview; RISE = Rating of Infant and Stranger Engagement; IBg = Indiscriminate Behavior group; IAg = Inhibited Attachment Group; NDBg = Non-disturbed Behavior Group; IB-Rg = Indiscriminate Behavior in the RISE Group; ~~N-IBg~~ N-IB-Rg = Non-Indiscriminate Behavior on the RISE group.

Table 2. Averages of peak amplitudes (in µV) across group, condition and laterality, in the first level of analysis.

Component	CG (n = 29)				~~IBg~~ IG (n = ~~23~~47)				IG subset of ~~N~~ IBg (n = ~~2~~45)			
	Caregiver's Face		Stranger's Face		Caregiver's Face		Stranger's Face		Caregiver's Face		Stranger's Face	
	M (SD)		M (SD)		M (SD)		M (SD)		M (SD)		M (SD)	
	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH
P1	13.21 (7.21)	15.26 (7.37)	13.86 (6.84)	15.27 (5.75)	11.57 (~~5.10~~5.85)	~~12.45~~13.46 (~~5.39~~6.00)	~~10.41~~11.21 (~~5.34~~5.40)	~~13.25~~13.17 (~~6.46~~6.01)	~~12.68~~7.85 (~~6.41~~6.44)	~~14.43~~8.58 (~~6.50~~6.38)	~~11.98~~6.37 (~~5.45~~5.22)	~~13.08~~8.15 (~~5.69~~5.58)
N170	-11.94 (5.36)	-11.07 (4.97)	-9.75 (4.67)	-8.90 (4.59)	-~~9.46~~9.68 (~~4.59~~5.05)	-~~8.61~~9.13 (~~3.61~~4.95)	-~~8.96~~9.06 (~~4.53~~5.50)	-~~7.52~~8.21 (~~4.20~~4.76)	-~~8.76~~10.13 (~~5.12~~1.99)	-~~9.83~~8.17 (~~5.57~~4.30)	-~~9.29~~10.11 (~~6.22~~2.68)	-~~8.90~~10.92 (~~5.21~~.99)
P400	8.93 (4.52)	9.20 (4.01)	8.39 (3.76)	8.42 (3.50)	~~7.33~~8.28 (~~4~~3.29 91)	~~6.75~~8.04 (~~3.83~~4.26)	~~7.21~~7.99 (~~3.73~~3.35)	~~6.52~~7.80 (~~3.54~~4.20)	~~9.02~~5.48 (~~3.04~~3.47)	~~9.28~~6.20 (~~4.36~~4.38)	~~8.71~~5.02 (~~2.74~~2.89)	~~8.93~~4.34 (~~4.43~~3.59)

Table 3. Averages of latencies to peak (in ms) across group, condition and laterality.

Component	CG (n = 29) Caregiver's Face M (SD)		Stranger's Face M (SD)		IBg (n = 23) Caregiver's Face M (SD)		Stranger's Face M (SD)		N-IBg (n = 24) Caregiver's Face M (SD)		Stranger's Face M (SD)	
	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH
P1	156	152	155	158	161	158	162	161	156	151	159	154
	(18)	(15)	(19)	(16)	(22)	(21)	(21)	(22)	(18)	(15)	(17)	(20)
N170	250	253	255	257	263	260	264	266	263	269	267	268
	(14)	(14)	(15)	(16)	(25)	(23)	(27)	(30)	(26)	(30)	(24)	(20)
P400	394	392	402	386	392	395	391	401	395	383	383	385
	(45)	(50)	(58)	(45)	(36)	(31)	(33)	(37)	(34)	(32)	(30)	(35)

Figure 3. N170 amplitudes per group, for each face type.
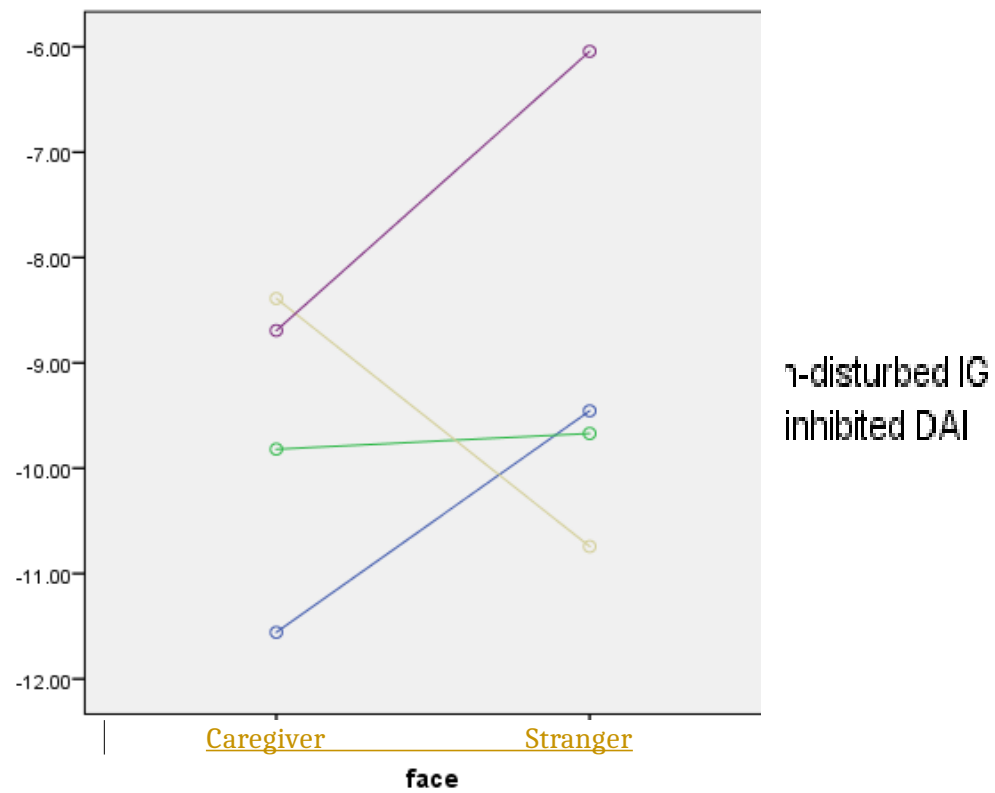
Note. CG = Comparison group; IBg = Indiscriminate Behavior group; N-IBg = Non-Indiscriminate Behavior group; LH = Left hemisphere; RH = Right hemisphere.

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