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CICLO XXVI

The effects of repetitive traumatic experiences on emotion recognition, Facial Mimicry and autonomic regulation

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"*The past is the present, it's possible to understand trauma as a form of speechlessness that is located in an ongoing present. Indeed, trauma victims live outside of time."*

Siri Hustvedt
The Shaking Woman or A History of My Nerves, 2010, p. 57

INDEX

I General Introduction 4

II Prolonged trauma in Sierra Leonean street-boys: when early experiences build a wall to others' emotion

II.a Introduction 11
II.b Method 16
II.c Results 21
II.d Discussion 27

III Prolonged trauma in Sierra Leonean street-children: evidence for anger recognition bias

III.a Introduction 30
III.b Method 32
III.c Results 34
III.d Discussion 42

IV Prolonged trauma in Sierra Leonean street-children: evidence for alteration of Facial Mimicry and vagal regulation to facial expressions of emotions

IV.a Introduction 45
IV.b Method 46
IV.c Results 50
IV.d Discussion 55

V The impact trajectories of early traumatic experiences

V.a Introduction 58
V.b Method 62
V.c Results 66
V.d Discussion 80

VI General Discussion and Conclusions 85

VII References 89

"*Man is by nature a social animal; an individual who is unsocial naturally and not accidentally is either beneath our notice or more than human. Society is something that precedes the individual. Anyone who either cannot lead the common life or is so self-sufficient as not to need to, and therefore does not partake of society, is either a beast or a god.*" (My Italics) This Aristotle's (PA I.2,1253a, trans. Ogle) universally known affirmation highlights the constitutive social nature of humans, suggesting that unsociality represents a feature completely foreign to human nature. Albeit not so sharply, neuroscientific research supports the intrinsic social nature of humans. Epitomizing the humans' congenital propensity for sociality, a recent study investigating the kinematic profiles of movements of twin fetuses found prenatal (14th and 18th week of gestation) 'social' interactions (Castiello et al., 2010). The social propensity of humans is more than evident even hours after birth, when newborns show early preparedness for social interaction that, among other things, is expressed in their imitation of others' facial expressions (A N Meltzoff & Moore, 1983; Andrew N Meltzoff & Moore, 1989).

Humans are indeed social animals, and virtually all of their actions are directed toward or are produced in response to others (Batson, 1990). In this context, the basic function of some rapid, spontaneous and widely shared human gestures, like facial expressions of emotions, can be understood. Facial expressions of emotions are a powerful vehicle of information by which humans communicate intentions, dispositions, feelings and emotional states to each other (Ekman & Oster, 1979). Their great communicative power enables the immediate understanding of others' purposes which is, along with the ability to effectively communicate our own internal states and dispositions, a crucial social skill. The recognition of facial expressions of emotion is particularly important because it represents the early utilization of social cues on which children's subsequent interpretations and behavioral responses will depend. Hence, the correct and rapid understanding of others' emotions, dispositions, intentions and feelings provides the basis for consistent social behavioral responses. For example, an immediate acceleration of the heart rate preparing defensive behavioral strategies (e.g., fight/flight) in front of an angry face, or a pulse deceleration inducing prosocial behavioral responses when we see others smiling, are coherent adaptations to the external social environment. It appears evident that an accurate recognition and classification of facial expressions of emotions is highly relevant for humans and their social interactions.

The explicit recognition of facial expressions of emotions gradually improves with age (Boyatzis, Chazan, & Ting, 1993; Herba & Phillips, 2004; Martínez-Castilla, Burt, Borgatti, & Gagliardi, 2014; Odom & Lemond, 1972; Philippot & Feldman, 1990). Even though very little is known about the continued development of emotion processing over the full childhood range into adolescence, general consensus is present in considering infancy and childhood as periods marked by exuberant changes in brain growth and significant advances in social and emotional development (Silk, Redcay, & Fox, 2014). Behavioral studies demonstrated that the recognition of emotional facial expressions starts early in infancy and continues through childhood, adolescence, and adulthood (Herba & Phillips, 2004). An improvement in the perception of facial expressions was shown between the age of 6 and 8 years, whereas little changes were evidenced until about 13 years, followed by a second improvement to adult performance at about 14 years (Kolb, Wilson, & Taylor, 1992). Coherently, despite the precocious utilization of facial expressions, the neural processing involved in the perception of emotional faces develops in a staggered fashion throughout childhood, with the adult pattern appearing only late in adolescence (Batty & Taylor, 2006). There is broad agreement in considering joy as the first facial recognized expression (Herba & Phillips, 2004). At a later stage, the categorization of negative facial expressions of emotions improves, with angry facial expression being first recognized first followed by sadness and fear expressions (Herba & Phillips, 2004).

Beside the explicit recognition of facial expressions of emotions, different studies demonstrate that also at an implicit, unconscious and automatic level facial expressions of emotions are effectively processed. In 1890, James observed that ‘‘Every representation of a movement awakens in some degree the actual movement which is its object.(p. 526)’’ Since then, a large number of studies found that observers tend to overtly and covertly mimic behavior of those around them. Specifically, people tend to mimic others’ gestures and body postures (Chartrand & Bargh, 1999), tone of voice and pronunciation patterns (Goldinger, 1998; Neumann & Strack, 2000), breathing rates (McFarland, 2001; Paccalin & Jeannerod, 2000) and even facial expressions of emotions (Dimberg, Thunberg, & Elmehed, 2000; Dimberg, 1982).

The automatic imitation of other people’s facial expressions has been called “Facial Mimicry”. Hence, it has been demonstrated that people exposed to negative and positive facial expressions of emotions, spontaneously (Dimberg, 1982) and rapidly (Dimberg & Thunberg, 1998) produce distinct facial electromyographic (EMG) activations in the same muscles involved in expressing the displayed positive and negative facial expressions.

Facial Mimicry has been explained in two ways. Some researchers propose that mimicry reflects the process of emotional contagion (Hatfield, Cacioppo, & Rapson, 1993; Laird et al., 1994). That is, observation of other’s emotional expressions first triggers the corresponding emotion in the observer which then elicits the same facial expression (Lundqvist & Dimberg, 1995). However, another interesting interpretation proposes that Facial Mimicry reflects an internal simulation of the perceived facial expressions in order to facilitate understanding of others’ emotions (V. Gallese, 2013; Vittorio Gallese, 2003; Iacoboni, 2009; Niedenthal, 2007). This latter interpretation is part of a broader approach of intersubjectivity called “Embodied Simulation”. The assumption of Embodied Simulation is that the internal reenactment provides useful information either through generation of peripheral feedback (e.g., facial muscles) or engagement of an ‘‘as if’’ loop in the somatosensory and motor cortices (e.g., face representation). This approach does not exclude the existence of more complex and propositional systems allowing others’ internal states understanding (e.g., Theory of Mind), but simply identifies the Embodied Simulation as one of them. Embodied Simulation posits that the capacity to understand others’ intentional behaviors, as well as others’ feelings and emotions, relies on a basic functional mechanism, which exploits the intrinsic organization of the motor system of primates (V. Gallese, 2013; Vittorio Gallese, 2003, 2007). For this reason the “Mirror Mechanism” is considered the neural mechanism facilitating Embodied Simulation. Mirror Neurons are visuo-motor neurons first discovered in macaques’ premotor area F5 and, later on, also in a sector of the posterior parietal cortex reciprocally connected with area F5 (V. Gallese, Gernsbacher, Heyes, Hickok, & Iacoboni, 2011), in the primary motor cortex (Vigneswaran, Philipp, Lemon, & Kraskov, 2013) and in the anterior cingulate cortex (de Araujo et al., 2012). These visuo-motor neurons respond when a goal related motor act is performed by the monkey, as well as, when the same motor-act is simply observed by the monkey (V Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). Hence, it appears that the observed action is reflected or internally simulated within the monkey’s own motor system. Today, the existence of a Mirror Mechanism is firmly established also in the human brain (Kilner, Neal, Weiskopf, Friston, & Frith, 2009; Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010). Human Mirror Mechanism is responsive also to symbolic gestures (Montgomery, Isenberg, & Haxby, 2007), others’ emotions (Hutchison, Davis, Lozano, Tasker, & Dostrovsky, 1999; Wicker et al., 2003) and sensations (Ebisch et al., 2008; Keysers et al., 2004). There is also specific evidence for the activation of the Mirror Mechanism when participants imitate other people’s facial expressions (L. Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003). Bearing in mind this evidence, it clearly appears that the Mirror Mechanism forms an important mechanism of shared representation (Decety & Chaminade, 2003; Oberman, Winkielman, & Ramachandran, 2007). In this context Embodied Simulation, among other things, aims at providing a functional description of the Mirror Mechanisms in the domains of action, emotions and sensations and related phenomena, providing an unitary account of basic aspects of intersubjectivity and showing that people reuse their own mental states or processes represented in bodily format to functionally attribute them to others (Vittorio Gallese & Sinigaglia, 2011; Vittorio Gallese, 2003).

Following this perspective, Facial Mimicry serves to automatically and non-consciously synchronize people's emotional disposition and promote social cohesion. In short, Facial Mimicry allows humans to increase their "interpersonal sensitivity" by "entering into others' worlds". This interpretation of the functional role of Facial Mimicry has been supported by a handful of studies regarding the decoding of facial expressions. For example, Oberman et al., (2007) blocked Facial Mimicry on the lower half of perceivers' faces and observed poorer recognition of happiness and disgust expressions, but no difference for sadness or fear (Oberman et al., 2007). Ponari et al (2012) replicated the findings for happiness and disgust, and further demonstrated that blocking mimicry of the upper face resulted in poorer recognition of anger. (Ponari, Conson, D'Amico, Grossi, & Trojano, 2012). These results are impressive because participants of the experiments viewed and classified facial expressions that were prototypic, and thus easily categorized. In other words, Facial Mimicry facilitates empathy, emotional reciprocity and recognition, and thus characterizes interpersonal relationships in a meaningful, affective fashion (Iacoboni, 2009).

An accurate explicit and implicit processing of other people's facial expressions allows the adoption of consistent behavioral adaptations to the external environment. Hence, during social interactions, others' facial expressions of emotions contribute to define the nature of the situation in which people are engaged. In other words, other people's facial expressions of emotions allow the observer to understand whether the contingent social environment is dangerous or safe, that is, whether threatening stimuli have to be expected or not. Behavioral regulation requires a synchronous and overall control of the entire body, which is carried out by the Autonomic Nervous System. The sympathetic and parasympathetic autonomic nervous subsystems represent antagonist, but coordinated, regulation mechanisms by means of which an appropriate internal state meets shifts in both internal and external demands. On the one hand, the sympathetic autonomic nervous subsystem allows an alerted and aroused state promoting defensive responses like fight–flight behaviors to thretening stimuli. On the other hand, the parasympathetic subsystem promotes a calm state consistent both with metabolic demands of growth and restoration and with social interactions. The main actor of the parasympathetic subsystem is the Vagus Nerve. The myelinated branch of the Vagus Nerve, which humans share with some mammals living in herds, thanks to the control of face striated muscles and of several visceral organs, contributes to the richness of human social behaviors. For example the myelinated branch of the Vagus Nerve is implicated in lower face expressivity, eye contact, prosody expression and middle ear muscles modulation to improve the extraction of human voice (Stephen W Porges, 2009).

The Polyvagal Theory provides a conceptual framework for understanding the link between autonomic subsystems and the regulation of social behavior (Beauchaine, Gatzke-Kopp, & Mead, 2007; S W Porges, 2003b; Stephen W Porges, 2009). The Polivagal Theory describes three anatomically and physiologically different autonomic subsystems each of which is respectively linked to immobilization (e.g., feigning death, promoted by unmyelinated vagus nerve), mobilization (e.g., fight–flight behaviors, fostered by sympathetic nervous system), and social communication (e.g., facial expressions, vocalisations and interpersonal contact, mediated by myelinated vagal fibers) (S W Porges, 2007). According to this perspective, the Autonomic Nervous System works as part of a social engagement system (Beauchaine et al., 2007; S W Porges, 2003b; Stephen W Porges, 2009) enabling individuals to assess risk and, if the environment is perceived as safe, to inhibit ineffective defensive behaviors and to recruit the parasympathtic subsystem, primarily associated with vagus nerve activities, promoting social interactions.

Respiratory Sinus Arrhythmia (RSA) is one of the periodic components of heart rate variability resulting from the coupling of cardiovascular and respiratory systems by which the ECG R-R intervals are shortened during inspiration and prolonged during expiration (Berntson, Cacioppo, & Quigley, 1993). It is formally defined as the heart rate variance (measured as R-R interval expressed in msec) across the band of frequencies associated with spontaneous respiration (0.12–0.40 Hz) (Allen, Chambers, & Towers, 2007). This modulation of heart rate in synchrony with respiration is physiologically carried out by the myelinated branch of the Vagus Nerve. Hence, RSA is defined as a valid index of the vagal influence on the heart (Stephen W Porges, 2009). Being this branch particularly implicated in the autonomic regulation of numerous social behaviors, as described by Porges, RSA is considered an indirect but consistent measure of humans' ability to adapt their autonomic responses to environmental social stimuli and to establish a physiological state suitable for social relations (i.e., ''self-regulation'' and ''social disposition'' skills) (S W Porges, 2003a). Coherently, individuals with low RSA and/or poor RSA regulation exhibit difficulties in regulating emotional state, in appropriately attending to social cues and gestures, and in expressing contingent and appropriate emotions (S W Porges, Doussard-Roosevelt, & Maiti, 1994). A significant RSA modulation has also been recorded during social interactions in function of social distance (Ferri, Ardizzi, Ambrosecchia, & Gallese, 2013). Recently, beside baseline RSA, attention has been given to RSA suppression. Higher baseline and greater RSA suppression are considered indexes of better ability to engage and disengage with the demands of environmental requests (J F Thayer & Lane, 2000). Accordingly, individuals with higher baseline RSA should show greater RSA suppression to meet metabolic demands of taxing environmental conditions, including threatening stimuli.

Considering the described explicit and implicit processes of others' facial expressions of emotions and their consequences in social interaction, it is not surprisling that the study of these processes along with the investigation of their typical and atypical social development draws the attention of Social and Affective Neuroscience perspective. Emerging research highlights the influence of social and emotional childhood experiences, and their interactions, on the developing brain. This approach recognizes that development, and particularly the social development, is nested within both biological and social contexts, and ultimately aims to chart how the dynamic interplay of biological, social, and emotional influences shapes developmental trajectories (Silk et al., 2014). At birth, human babies are the most helpless of all mammals. Human infants have a protracted period of development compared to other species (Glaser, 2000). This lengthened time for learning allows for the development of a far superior intellect (compared to other animals). However, the plasticity and adaptability of the young human brain also makes it very vulnerable to adverse environmental influences. Sensitive periods have been identified during which the developing brain is especially responsive to environmental input (Glaser, 2000). Neurotrophins are one putative mechanism by which the environment can shape the brain, because of its role in regulation of neuronal survival and differentiation. The secretion of neurotrophins is regulated by neuronal activity, which is directly related to environmental input (Glaser, 2000). Two facets of these environmentally dependent brain maturational processes have been described, i.e. "experience-expectant", and "experience dependent" processes. Experience-expectant deficits occur when failure of environmental stimulation during critical periods of brain development may lead to permanent problems (Glaser, 2000). A relatively recent example would be infants in Romanian orphanages, where a single caretaker is responsible for up to 60 babies (De Bellis, 2005; Smyke et al., 2007). Children reared in orphanage were found to have delayed growth, gross motor skills and language, neuroendocrine dysregulation, altered neural development, as well as deficit in facial and emotions recognition (De Bellis, Hooper, Spratt, & Woolley, 2009; De Bellis, 2005; Fries, Shirtcliff, & Pollak, 2008; Moulson, Westerlund, Fox, Zeanah, & Nelson, 2009; Nelson, Westerlund, Mcdermott, Zeanah, & Fox, 2013; Sheridan, Fox, Zeanah, McLaughlin, & Nelson, 2012; Smyke, Zeanah, Fox, Nelson, & Guthrie, 2010; Zeanah et al., 2009). These poor outcomes are generally associated with the period of institutionalization (De Bellis, 2005).

The other type of environmentally dependent brain maturational processes is known as experience dependent. In these experience-dependent deficits, new synapses are formed in response to environmental input (Glaser, 2000) generating aberrant adaptation of low and high level processes. An exemplificative case are physically abused children who show specific deficits in the explicit recognition of facial expressions of emotions. Hence, victims of physical abuse recognize angry facial expressions on the basis of less sensory inputs (Pollak & Sinha, 2002) and thanks to fewer expressive cues (Pollak, Messner, Kistler, & Cohn, 2009) with respect to age-matched children with no abuse history. That recognition bias for angry facial expressions has been interpreted as a specific form of learning in which the pre-existing perceptual and attentive mechanisms are adapted to process environmental aspects that become especially salient, like angry facial expressions (Pollak & Tolley-Schell, 2003; Pollak, Vardi, Putzer Bechner, & Curtin, 2005). This interpretation strengthen the notion that irrespective of the initial state of the organism, emotional development is contingent on the nature of the inputs and experiences made available to the child (Pollak, Cicchetti, Hornung, & Reed, 2000).

In general, it has been suggested that early neglect leads to deprivation of input needed by the infant brain at times of experience-expectant maturation, while abusive experiences affect brain development at experience-dependent stages (Glaser, 2000). However, this sharp distinction can be only formally described, since childhood neglect and abuse traumatic experiences are frequently co-present.

Child abuse is defined as an act, which creates an actual or potential physical or mental risk to a child under 18 years of age (Panzer, 2008). It is subdivided in to physical, emotional or sexual abuse. These abusive acts can occur once, repeatedly or can be a pattern of interaction in a dysfunctional relationship with a caregiver. Child neglect is defined as an omission of care, which creates an actual or potential physical or mental risk to a child under 18 years of age (Panzer, 2008). It is subdivided into physical, emotional, medical or educational neglect. Generally, various subtypes of abuse and neglect often coexist. Outcomes of childhood trauma exposure are dependent on the subtype(s), severity, frequency and chronicity of abuse and neglect, as well as on children characteristics like age, gender, temperament and any disabilities (De Bellis, 2005; Glaser, 2000; Panzer, 2008). The onset age of child maltreatment was found to predict long-term mental health outcome, as would be expected with stressors negatively impacting on neurodevelopment (Kaplow & Widom, 2007). Furthermore, maltreated children and their caregivers often live in poverty and under difficult social circumstances. Hence, children are likely to suffer many other adversities such as prenatal exposure to substances, witnessing domestic violence, poor nutrition and lack of educational opportunities. All these variable can influence trauma exposure effects. In this perspective, the empirical attempts to investigate the effects of one traumatic event on a narrow homogeneous population (e.g., intra-familiar sexual abuse among mid-classes females), even if potentially informative on the specific influence of that kind of trauma, result artificial and non-ecological. On the contrary, the involvement of wide and uneven sample of participants exposed to different forms of trauma results an efficient strategy to overcome these consistent problems because it allows to minimize the impact of varied and frequently unmeasured characteristics of specific stressful experiences maintaining, at the same time, an ecological sample representation. Moreover, it is important to note that the timing, chronicity, and scope of stress may differ greatly between groups; however, the end-state (dependent measures) could be similar across populations (Hanson et al., 2014).

An exemplificative case of childhood experience of high levels of maltreatment and neglect is the case of street-children. There are many definitions for street-children, but the definition introduced by Inter-NGO Program (UNCHS, 2000) covers important dimensions: "Any girl or boy … for whom the street (in the widest sense of the word, including unoccupied dwellings, wasteland, etc.) has become his or her habitual abode and/or source of livelihood; and who is inadequately protected, supervised, or directed by responsible adults". International reports reveal that the exact number of street-children is impossible to quantify, but the figure almost certainly runs into tens of millions across the word (UNICEF, 2005). Despite the characteristics of street-children are diverse and change by location, by context and over time, the majority of street children are boys (le Roux & Smith, 1998; Lugalla & Mbwambo, 1999). They generally start living on the streets between 9 and 12 years old, and they keep living on the streets until they reach the age of 15 to 16 (Rizzini, 1996). Street-children suffer from high levels of neglect: they face difficulties in providing themselves with good sources of food, clean drinking water, health care services, toilets and bath facilities, and adequate shelter. They also suffer from absence of parental protection, and security and education due to the missing connection with their families. In addition, there is a lack of any kind of moral and emotional support (Lugalla & Mbwambo, 1999). Furthermore, they are also expose to high levels of maltreatment: they act or suffer of intimidation, robberies, and sexual or physical assaults in the street. Moreover, they are subject to dangerous and illegal activities such as drug dealing, crime, theft and gang activities (UNCHS, 2000).

Living as street-children constitutes a specific adverse childhood experience, in which high levels of maltreatment and neglect occur. Street-children's life condition is characterized by the exposure to different forms of abuse and neglect experienced in a repetitive and cumulative manner. Furthermore, street-children's life condition is a time protracted state which can cover the individuals' entire childhood and adolescence.

Recent studies demonstrate that living in these hostile conditions, not only is associated with high levels of serious psychiatric sequelae, but it also increases the risk to develop them. In an explicative study, it has been demonstrated that cumulative street victimization nearly doubled youths' odds for meeting criteria for substance abuse disorder and depression (Bender, Brown, Thompson, Ferguson, & Langenderfer, 2014). Moreover, in a population of street-children who experienced many traumatic events and high violence levels, even minor violent events may trigger and reinforce PTSD symptoms (Crombach, Bambonyé, & Elbert, 2014). Fortunately, the outcome of certain adverse experiences are limited by protective factors, like individual resilience and support from other persons (Glaser, 2000; Oppong Asante & Meyer-Weitz, 2015) which may reduce the damage. In addition to these findings it has been demonstrated that repetitive, cumulative and prolonged traumatic childhood events, induce specific outcomes related to affective dysregulation, negative self-concept, and interpersonal problems (Cloitre et al., 2009; Cloitre, Courtois, Carapezza, Stolbach, & Green, 2011; Cloitre, Garvert, Brewin, Bryant, & Maercker, 2013; Cloitre, Garvert, Weiss, Carlson, & Bryant, 2014; Ginzburg & Solomon, 2011). Specifically, low emotions understanding, low empathic resonance as well as incoherent behavioural reactions to external social stimuli have been described (Cloitre et al., 2013). These clinical observations have been confirmed by several studies demonstrating that prolonged conditions of maltreatment and neglect induce significant changes not only in the overall brain activity and anatomy, but especially in cerebral regions involved in self-regulation and emotion understanding (Hanson et al., 2013, 2014; Hanson, Chandra, Wolfe, & Pollak, 2011; Sheridan, Fox, Zeanah, McLaughlin, et al., 2012; Teicher, Anderson, Ohashi, & Polcari, 2014). Coming back to the initial part of Introduction, it appears evident that the explicit recognition of facial expressions of emotions, Facial Mimicry and vagal regulation responses to others' facial expressions of emotions, represent index of individuals' abilities to understand emotions, to empathically respond to them and consequently to effectively adjust behavioural responses.

The present dissertation aims to explore the influence of high levels of maltreatment and neglect on explicit recognition, Facial Mimicry and vagal regulation in response to facial expressions of emotions, considered a crucial social cue for understanding others' emotion, feelings, intentions and dispositions and for the subsequent behavioural responses. To this aim populations of Sierra Leonean street-children and street-boys were involved in a forced-choice facial expressions of emotions recognition task, and in a perceptual task facial expressions of emotions during which facial EMG and RSA responses were recorded.

In the second Chapter of the present dissertation, we will focus on an adolescent population of street-boys exposed to protracted high levels of maltreatment and neglect. We will demonstrate how this condition induces, along with an explicit recognition bias for angry facial expressions, a significant suppression of Facial Mimicry to both positive and negative facial expressions of emotions and an ineffective suppression of vagal regulation in response to non-threatening expressions.

In the third and fourth Chapters we will extend previous findings investigating a younger population of street-children. The presence of a bias in the recognition of angry facial expressions among children currently exposed to high levels of maltreatment and neglect will be described in the third Chapter, where the occurrence of a similar tendency among age-matched controls, suggests that early exposure to maltreatment worsens children's bias towards the identification of specific negative facial expressions. The fourth Chapter will point out a differentiated influence of childhood exposure to high levels of maltreatment and neglect on Facial Mimicry and vagal regulation. It will be shown that whereas early traumatic experiences induce an alteration of Corrugator EMG modulation by positive and negative facial expressions functional to emotional valence discrimination, the same participants show an earlier development of the functional synchronization between vagal regulation and threatening stimuli in the external environment.

Finally, in the fifth Chapter the impact trajectories of trauma exposure on the explicit recognition of facial expression of emotions, Facial Mimicry and vagal regulation will be investigated. Results will delineate a differentiated influence of trauma exposure on the investigated fields.

II.a Introduction

Emerging researches from the Social and Affective Neuroscience highlight the influence of social and emotional childhood experiences, and their interactions, on the developing brain. This approach recognizes that development is nested within both biological and social contexts, and ultimately aims to chart how the dynamic interplay of biological, social, and emotional influences shapes developmental trajectories (Silk et al., 2014). In this context, the study of typical and atypical development in children and adolescents has become increasingly informed by, and integrated with, Social and Affective Neuroscience perspectives. For the present dissertation, researches regarding the effect of childhood traumatic experiences, like child abuse, maltreatment and neglect, on emotion processing, as a key component of social interaction, are particularly interesting.

A wide range of studies demonstrated that childhood and early negative experiences influence facial expressions of emotions recognition. For example, physically abused preschooler infants, as well as, children above 6 years of age, showed specific deficits in recognizing negative facial expressions of emotions. Children with physical abuse histories presented a response bias for angry facial expressions. They showed significantly higher erroneous anger attribution (i.e., Angry False Alarms Rate) than children with no prior physical abuse trauma in an emotion recognition task (Pollak et al., 2000). Moreover, angry facial expressions were recognized on the basis of less sensory inputs (Pollak & Sinha, 2002) and thanks to fewer expressive cues (Pollak et al., 2009) by physically abused children than controls. When a categorical discrimination of morphed facial expressions created combining two different emotions (e.g., happy/fear, happy/sad, angry/fear, angry/sad), was required, abused children displayed equivalent category boundaries to controls when discriminating morphing showing continua of happiness blended into fear and sadness facial expressions. However, these same children evinced extended category boundaries when discriminating angry faces blended into either fear or sadness facial expressions (Pollak & Kistler, 2002). The impact of physical abuse experiences on the recognition of facial expressions of emotions is not restricted to visual stimuli, but it concerns multimodal expression of emotions. Indeed, it was demonstrated that abused children were biased to rely on auditory cues when their own abusive mother was expressing anger (Shackman & Pollak, 2005). These behavioral results were coherent with event-related potentials (ERPs) investigation of neural correlates of facial affect processing in maltreated and non-maltreated infants. Findings revealed that maltreated infants at 42 months of age had greater P1 and P400 amplitude (i.e., two ERP components associated to face sensitivity) in response to angry facial expressions compared to other emotions, and compared to non-maltreated children (Curtis & Cicchetti, 2011). These electrophysiological results confirmed that the experience of maltreatment alters the functioning of neural systems associated with the identification and processing of facial expressions of emotions even at a very early stage of development.

Recent researches examined emotion recognition also among neglected children. Impoverished social and emotional environments, which are often present in cases of neglect, prevent the development of normal emotional skills and may cause a blunted pattern of emotional reactivity (Pollak et al., 2000). Pollak et al. (2000) reported that neglected children had more difficulty in recognizing emotional expressions in a vignette than a control group or physically abused children. Moreover, when rating the similarity between facial expressions of different emotions, neglected children saw fewer distinctions between emotions compared to the other two groups (Pollak et al., 2000). Other studies focused on post-institutionalized children grown-up in an institutional care for their first two years of life, prior to adoption into family environment. Internationally adopted post-institutionalized children, even tested at 4 years of age, presented difficulties in identifying facial expressions of emotion. In addition, they had significant difficulty matching appropriate facial expressions to happy, sad, and fearful scenarios. However, post-institutionalized children performed as well as control children when asked to identify and match angry facial expressions (Fries & Pollak, 2004). In a recent study, Nelson et al., (2013) examined the ability to discriminate facial expressions among 8-year-old children who had been abandoned and placed in institutions in infancy and children with no institutional rearing (Nelson et al., 2013). Similarly to what demonstrated by Curtis et al., (2011) among maltreated infant, Nelson et al., (2013) evidenced that neglected children had significantly higher P1 to angry facial expression than age matched controls.

Taken together these empirical researches demonstrate that early experiences of physical abuse and neglect, influence children recognition of facial expression of emotion causing, in the majority of cases, a bias for angry facial expressions recognition or an overall lower accurate discrimination between negative facial expressions. In this scientific background, some contradictory results have to be mentioned. Evaluating the performance of abused and neglected children at “Reading the Mind in the Eyes Task” (RMET), Koizumi et al., (2014) evidenced that the mean accuracy rate on the RMET for abused children was significantly lower than the rate of the non-abused children. However, whereas accuracy rates for positive emotion items (e.g., hoping, interest, joy) were significantly lower for the abused children than controls, accuracy rates for negative emotion and neutral items were not different across the two groups (Koizumi & Takagishi, 2014). Differently, 8- to 10-year-old Romanian children abandoned to institutions showed higher thresholds for identifying joy expressions than age-matched foster care or community children, but did not differ in their thresholds for identifying the other facial expressions (Moulson et al., 2014). Finally, Masten et al. (2008) showed that maltreated children displayed faster reaction times than controls when labeling fear facial expressions, whereas, no group difference was demonstrated in labeling of emotions when identifying different facial emotions (Masten et al., 2008). Differences in negative events exposure, as well as differences in sample age and experimental paradigms used, could account for those contradictory results.

Overall, alterations in explicit recognition of facial expressions of emotions following childhood abuse, maltreatment and neglect could be interpreted as a specific form of learning in which biological, social, and emotional influences shape developmental trajectories. Children and young adults exposed to early aversive experiences, adapt their pre-existing perceptual and attentive mechanisms to process environmental aspects that become especially salient. Pollak et al. (2005) suggest that in abusive home environments, children learn to associate anger with threat of harm and therefore, they are hyper-vigilant to anger (Pollak et al., 2005). Coherently, maltreated children showed larger P3b (i.e., ERP component reflecting the amount of attentional resources engaged) amplitude during attentive task when angry faces appeared as targets than did control children (Pollak, Klorman, Thatcher, & Cicchetti, 2001), as well as an enhanced selective attention to angry facial expressions posed by their mothers (Shackman, Shackman, & Pollak, 2007). When engaged in an experimental variant of the well-known Posner attentive task employing facial expressions of emotions as stimuli, physically abused children demonstrated delayed disengagement when angry faces served as invalid cues, and increased attentional benefits on valid angry trials (Pollak & Tolley-Schell, 2003). The greater attentive focus on angry environmental stimuli was demonstrated also in a realistic interpersonal emotional situation during which physically abused children increased anticipatory monitoring of the environment (Pollak et al., 2005).

The studies here described focused on child physical abuse, maltreatment and neglect, conditions that could be described as repetitive and prolonged traumatic experiences. Frequently the abuses occurred in familiar environment and were perpetrated by parents or relatives, suggesting the presence of a broad hostile milieu. In the case of neglect experiences, children lived for different periods in institution or orphanage sadly known for the lower level of affective care. Nevertheless, the recognition bias for angry facial expressions recognition has been found also following single acute traumatic experience. Scrimin et al., (2009) investigated the effects of the terroristic attack to Beslan school on children’s ability to recognize emotions.

Results demonstrated that, compared with non-exposed children, exposed children labeled ambiguous facial expressions constituting by both anger and sadness significantly more often than expected as anger, and produced fewer correct answers in response to stimuli containing sadness as a target emotion (Scrimin, Moscardino, Capello, Altoè, & Axia, 2009). This result suggests that even the exposure to a single traumatic event could induce an immediate modulation of victims' perceptual and attentive mechanisms.

Different studies examined the long-term effects of childhood abuse on emotion recognition. Young adults reporting a history of moderate to severe childhood abuse exhibited, at the age of 19.24-year-old, preferential attention to angry faces and increased sensitivity in the detection of angry expressions at lower levels of emotional intensity when submitted to a modified version of a dot-probe task (Gibb, Schofield, & Coles, 2009). Moreover, adults (mean age = 47-year-old) with a history of childhood maltreatment, resulted overall less accurate in emotion processing, and especially, in processing positive and neutral pictures than age-matched controls (Young & Widom, 2014). Young & Widom (2014) demonstrated that trauma type and individual IQ level mediated the effect on explicit facial expressions recognition. Childhood physical abuse and sexual abuse predicted less accuracy in neutral pictures and less accuracy in recognizing positive pictures, respectively. Moreover, IQ acted to mediate the relationship between child maltreatment and emotion processing deficits. Interestingly, in a study conducted on former child-soldiers and non-combatant civilians who actively and passively participated to Sierra Leonean civil war, authors demonstrated a bias in negative facial expressions of emotions recognition (Umiltà, Wood, Loffredo, Ravera, & Gallese, 2013). Both former child-soldiers and civilians made more errors in identifying expressions of sadness, generally described as anger (bias for angry facial expression). Conversely, when making erroneous identifications of anger, fear and joy facial expressions, participants were most likely to label the expressed emotion as sadness although the latter was the worse recognized facial expression. These studies demonstrate a pervasive long-lasting effect of childhood exposure to traumatic experiences on the explicit recognition of facial expressions of emotions.

In summary, although employing different approaches (i.e., behavioral or electrophysiological measures), involving participants of different age (i.e., infants, pre-school or school-age children, adolescents and adults) and considering a variety of traumatic repetitive experiences (i.e., physical abuse, maltreatment, neglect) studies agree with the description of consistent effect of prolonged childhood traumatic experiences on the explicit recognition facial expressions of emotions that could be present also among adult population.

The exposure to multiple and repeated forms of trauma, like physical abuse, maltreatment and prolonged neglect, during childhood leads to outcomes that are not simply more severe than the sequelae of single incident trauma, but are also qualitatively different (Cloitre et al., 2009, 2011, 2013, 2014; Ginzburg & Solomon, 2011). Latent Profile Analysis conducted to determine whether people exposed to protracted trauma (e.g., childhood abuse) or to single-incident events (e.g., exposure to 9/11 attacks) are classes of individuals that are distinguishable according to symptom profiles, demonstrated that chronic trauma was strongly predictive of elevated PTSD symptoms (i.e., Re-experiencing, Avoidance, Sense of threat) as well as disturbances in three domains of self-organization: affective dysregulation, negative self-concept, and interpersonal problems (Cloitre et al., 2013). The presence of these three latter types of disturbances, which are pervasive and occur across various contexts and relationships regardless of proximity to traumatic reminders, is so solid to require the formulation of a new diagnostic category called Complex PTSD (Post Traumatic Stress Disorder) (Cloitre et al., 2013) beside the well-known PTSD.

Problems in the affective domain are characterized by emotion dysregulation as evidenced by heightened emotional reactivity, violent outbursts, reckless or self-destructive behavior, and a deficient self-regulation. Self-disturbances symptoms include negative self-concept marked by persistent beliefs about oneself as diminished, defeated or worthless. These beliefs can be accompanied by deep and pervasive feelings of shame or guilt related to, for example, not having overcome adverse circumstances, or not having been able to prevent the suffering of others. Finally, interpersonal disturbances are defined by difficulties in feeling close to others, deficit in empathic understanding of others' emotions and feelings and reduced interest in relationships and social engagement.

Recent researches in Social and Affective Neuroscience provide empirical support to these clinical observations. Childhood exposure to prolonged conditions of maltreatment and neglect induce significant changes not only in the overall brain activity and anatomy, but especially in cerebral regions involved in self-regulation and emotion understanding. Smaller total gray matter volume was found among pre-scholar infants from low-income families (Hanson et al., 2013) and in 8-year-old children with prior histories of institutional rearing (Sheridan, Fox, Zeanah, Mclaughlin, & Nelson, 2012). Coherently, compared with never-institutionalized infants, EEG recording of institutionalized Bucharest infants showed a pattern of increased low-frequency (theta) power in posterior scalp regions and decreased high-frequency (alpha and beta) power, particularly at frontal and temporal electrode sites (Peter J Marshall & Fox, 2004). Neuroanatomical study, using MRI technique, evidenced smaller orbitofrontal volumes in children who have suffered early aberrant parental care in the form of physical abuse (Hanson et al., 2010). The orbitofrontal region belongs to the cerebral circuit involved in adaptation to changing environmental contingencies and plays an important role in the control of emotion and motivational states. Reduced cerebral volume was also found in medial brain regions, like the hippocampus and the amygdala, in children exposed to early neglect, low socio economics status and physical abuse (Hanson et al., 2014, 2011). These pieces of evidence are crucial considering the role of those brain regions in long-term memory and emotional functioning. Studies investigating adults who reported history of childhood maltreatment and abuse demonstrated that these anatomical alterations persist over time (Teicher et al., 2014; van Harmelen et al., 2010). Interestingly, Teicher et al., (2014) demonstrated an altered network centrality of Cingulate, Precuneus, Temporal Pole and Insula cortices among adults reporting childhood maltreatment. Regions involved in emotional regulation and in the ability to accurately attribute thoughts or intentions to others showed a decreased centrality in favor of regions involved in internal emotional perception, self-referential thinking, and self-awareness.

Unexpectedly, fewer and contradictory empirical studies investigated the influence of early traumatic experiences on victims' Facial Mimicry responses to others' emotion. Physically maltreated children exhibited greater Corrugator EMG activations and more aggressive behavior in response to peer angry facial expressions, compared to non-maltreated children (Shackman & Pollak, 2014). On the contrary, high-betrayal abuse woman showed more mimicry of joy and less mimicry of angry facial expressions relative to women who reported no- or low-betrayal abuse, who showed the opposite pattern (Reichmann-Decker, DePrince, & McIntosh, 2009). The investigation of these aspects should gain greater attention considering Facial Mimicry as one of the physiological mechanisms related to empathic understanding of others' emotions (see Chapter I for a detailed description of Facial Mimicry).

Another field of research, supporting the presence of affective and self-regulation deficits following early exposure to repetitive traumatic experiences, investigates the alterations of Autonomic Nervous System (ANS). As extensively described in the Introduction (see Chapter I), behavioral self-regulation requires a synchronous and global control of the body, which is carried out by the ANS. The parasympathetic and sympathetic autonomic nervous subsystems represent antagonist, but coordinated, regulation mechanisms by which an appropriate internal state meets shifts in both internal and external demands. The parasympathetic subsystem, predominantly represented by vagal activity, promotes a calm state consistent both with metabolic demands of growth and restoration and with social interactions. In this context it is not surprising that adolescent females exposed to childhood maltreatment showed reduced vagal activity at baseline when compared to non-maltreated age-matched controls (Miskovic, Schmidt, Georgiades, Boyle, & MacMillan, 2009). Coherently, when involved in social interactions, children with abuse and maltreatment history, manifested lower or incoherent Respiratory Sinus Arrhythmia values (RSA, see Chapter I for an exhaustive description of RSA as index of vagal activity) (Oosterman, De Schipper, Fisher, Dozier, & Schuengel, 2010;

Skowron, Cipriano-Essel, Gatzke-Kopp, Teti, & Ammerman, 2014). Interestingly, Oosterman et al., (2010) highlighted an RSA increased RSA on separation and decreased RSA on reunion in children with a background of neglect during the "strange situation" task. Furthermore, low RSA levels during a joint task seem to predict the lowest inhibitory control of involved maltreated children (Skowron et al., 2014). Coherently, high RSA levels recorded during the visualization of a conflictual interactions, has been demonstrated to be protective against the effects of maltreatment on aggressive behavior in a sample of abused youth (Gordis, Feres, Olezeski, Rabkin, & Trickett, 2010). In agreement with this empirical evidence demonstrating a reduced parasympathetic regulation promoting social engagement among children exposed to repetitive trauma, Wismer Fries et al., (2005) reported that children who had experienced early neglect had lower overall lower levels of Ariginine Vasopressin, a critical neuropeptide in the establishment of social bonds and in the regulation of emotional behaviors, when compared with family-reared children (Fries, Ziegler, Kurian, Jacoris, & Pollak, 2005). Focusing on sympathetic body regulation, studies suggested a heightened reactivity of the sympathetic nervous subsystem, as well as of the related Hypothalamic-Pituitary-Adrenal (HPA) axis and neuroendocrine cortisol regulation. Young individuals with histories of severe neglect showed elevated levels of cortisol, in comparison to youths with lower or minimal levels of neglect. Moreover, prior severe neglect resulted also associated with increased levels of Macrophage Migration Inhibitory Factor (MIF), a cytokine known to be intricately involved in HPA axis regulation (Bick et al., 2014). Coherently, when maltreated and neglected children were exposed to acute laboratory stressors (Cook, Chaplin, Sinha, Tebes, & Mayes, 2012) or to a forced contact with the caregiver (Fries et al., 2008) an elevated cortisol level was recorded. Remarkably, children who had reportedly experienced more severe socio-emotional neglect showed greater elevations in cortisol levels following the interpersonal interaction with their mothers as compared to children who also experienced institutionalized rearing but who experienced less severe or no neglect (Fries et al., 2008). It is crucial to highlight that individual variables could modulate the neuroendocrine regulation following early aberrant experiences. As revealed by Pollak's group in a recent study (Seltzer, Ziegler, Connolly, Prososki, & Pollak, 2014) girls who have experienced early life stress in the form of child maltreatment released higher levels of urinary Oxytocin following exposure to a social stressor than their peers. Furthermore, although control girls showed high levels of cortisol after experiencing a social stressor, maltreated girls had comparatively low levels of cortisol before, during, and after the social stress task. These effects appear to be specific to girls as no differences were observed between maltreated and control boys with respect to Oxytocin or Cortisol. In a similar vein, recording systolic blood pressure, Leitzke et al., (2013) evidenced among maltreated youth an attenuated cardiovascular response to an acute interpersonal stressor relative to their non-maltreated peers (Leitzke, Hilt, & Pollak, 2013). Consistently, with the suggestion of an high variability among sample including children or youth exposed to early traumatic experiences, Doom et al., (2014) demonstrated in a longitudinal study, that maltreated children showed higher variance in the basal cortisol levels and slope over time compared to non-maltreated children, indicating greater between-person variability in the maltreated group. Maltreated children with higher cortisol at the first assessment showed cortisol suppression over time, indicating potential HPA blunting after chronic high cortisol levels. Moreover, the severity, timing, and number of subtypes of maltreatment predicted individuals' cortisol variability (Doom, Cicchetti, & Rogosch, 2014). Thus, huge variability is endogenous in samples composed by abused, maltreated and neglected children. A formal distinction between traumatic experiences, events of life, socio-economic states or other interfering variables, may be not only impossible but also captious. Regardless of these different results, taken together these studies demonstrated that aversive early experiences induce an autonomic dysregulation compromising self-regulation during social interactions and stress conditions.

The previously described empirical researches focused on Facial Mimicry and autonomic regulation alterations following childhood exposure to maltreatment and neglect, employing victims' in stress conditions or interpersonal interactions. No study investigated the Facial Mimicry and vagal regulation in response to the exposure to others' positive and negative facial expressions of emotions. Facial expressions of emotions are among the most powerful vehicles of information through which humans communicate intentions, dispositions, feelings and emotional states to each other. Their great communicative power enables the immediate understanding of others' purposes, which provides the basis for consistent social behavioral responses. Consequently, the breakdown of others' intention understanding could induce serious alterations in behavior regulation. As previously illustrated, childhood exposure to severe conditions of maltreatment and neglect induces a bias in angry facial expressions recognition. From this perspective, the study of Facial Mimicry and vagal regulation during the perception of positive and negative facial expressions becomes crucial to better understand the huge impact of early aversive experiences on interpersonal relationships.

The aim of the present study was to investigate if the explicit recognition of facial expressions of emotions, Facial Mimicry and vagal regulation could be altered in an sample of adolescents currently exposed to high levels of both maltreatment and neglect. To this goal a sample of Sierra Leonean street-boys, all males, was submitted to a forced-choice facial emotion recognition task. Moreover, Facial EMG and RSA responses to positive and negative facial expressions of emotions were recorded as indexes of empathic understanding of others' emotions end self-regulation, respectively.

In agreement with previous results we expected to find a bias for angry faces among street-boys but not among controls. If a bias for anger were present this label should be over-attributed to other negative facial expressions of emotions. The averse environment in which street-boys grew-up is characterized by higher level of competition, violence and aggressiveness. In this context an empathic resonance to others' emotions, by means of facial mimicry, is not adaptive. Accordingly, we expected to find lower Facial Mimicry response to facial expressions in street-boys than controls. A deficit of Facial Mimicry, developed as an adaptation to aversive early experiences, could diminish social understanding and magnify defensive behavior. If this were the case, lower baseline RSA after stimuli visualization and non-functional RSA suppression during the visualization of non-threat facial expressions should be expected among street-boys.

II.b Method

Participants

A total of 60 participants were recruited for the study. Participants with cardio-respiratory or psychiatric diseases, users of drugs interfering with the cardio-respiratory activity and heavy smokers (>25 cigarettes per day) were excluded. Moreover, participants who had more than 30% of trials rejected for artifacts were also excluded. These exclusion criteria resulted in a final sample of 41 participants. Of these 19 were street-boys recruited in the Juvenile Prison of Freetown [Street-Boys group (SBg); mean age 15.7 years SE 0.3; mean years of schooling 7.1 SE 0.8; all males] and 22 were students in the Holy Family School of Freetown [Control group (Cg); mean age 15.9 years SE 0.3; mean years of schooling 5.3 SE 0.7; all males].

Boston Naming Test (BNT; Kaplan, Goodglass, Weintraub, & Segal, 1983) was submitted to all participants. BNT assesses visual naming ability and word retrieval through 60 line drawings graded in difficulty and frequency. It is frequently administered to healthy children and adults as well as to aphasia and dementia patients. Here, it was selected to assess possible differences between groups difference in labeling skill, and so, to avoid confounding effect on behavioral results. No differences were found between groups in BNT performance [SBg: 24.3 SE 1.8; Cg: 22.7 SE 0.9; $t_{39} = 0.87$, $p = 0.39$], age [$t_{39} = -0.44$, $p = 0.66$], and years of schooling [$t_{33} = 1.52$, $p = 0.14$]. Most participants came from the ethnic group of Krio and Temne, 34% and 32% of the sample, respectively. All participants in the SBg were street-boys in their first-time in jail; 73% of SBg had committed and experienced intense physical violence. They were all characterized by an extreme level of social deprivation, marginalization and neglect in the years preceding their arrest. Most had left parents' home before the age of ten and on average they lived in the street for six years without the presence of a stable adult figure in their lives. None of the participants in the Cg were street-boys or had ever been in prison. They lived with their parents or close relatives. Written informed consent was obtained from the legal tutors and guardians of participants. Verbal consent was obtained from participants. A local social worker explained to the participants how the research would be conducted and asked if they would be available to collaborate with us. We sought oral consent from the participants, with the social worker serving as witness since, some of them were illiterate and most better understood the oral instruction given by the social worker. The experimental protocol, and the modalities by which the informed consent was collected were approved by the Ethics Committee of ASL1 of Imperia, Italy and by the Ethics Committee of the Ministry of Health and Sanitation of the Republic of Sierra Leone.

Procedure

The experimental session consisted of two experiments: the behavioral experiment was a forced-choice facial emotion recognition task and the physiological experiment was a simple perceptive task conducted to record Facial Electromyography (Facial EMG) and Respiratory Sinus Arrhythmia (RSA) responses to the stimuli. The behavioral and physiological responses were recorded in two separate experimental sessions to avoid potentially confounding effects of verbal responses and of mental-stress occurring during emotion recognition task on electrophysiological measurements (Bernardi et al., 2000; Sahar, Shalev, & Porges, 2001; Tininenko, Measelle, Ablow, & High, 2012). The order of the experiments was balanced between participants. The entire experimental session for both groups of participants was conducted using the same experimental setting and at the same location, the seat of the Murialdo's Josephites Mission in Kissy (Freetown). All participants of the SBg obtained a special permit to leave the Juvenile Prison for the time of the experiments. A local social assistant was always present to ensure that participants remained at ease, understood the instructions and to translate from English to Krio, if necessary.

Stimuli employed in both experiments were 64 video-morphing constructed by using the Montreal Facial Displays of Emotion stimulus set (MSFDE; Beaupre, 2005). The video-morphing, lasting 3000 msec (15 fps; 800×560 pixels), showed the transition from a neutral facial expression to an emotional one (16 anger, 16 fear, 16 joy and 16 sadness). Each emotion expression was modeled by Asian, African, Hispanic and Caucasian actors balanced for gender (4 stimuli for each ethnic group, 2 males and 2 females). Stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Inc.).

Behavioral experiment (Figure 1)- Participants sat comfortably at a table, in front of a computer monitor (1024X768@75Hz). They were asked to pay attention and to observe each stimulus for its entire duration. Stimuli were presented once (64 trials, 16 trials for each emotion: anger, fear, joy and sadness) in random order. After each stimulus, with no time limit, participants were asked to identify which of the four alternative labels (anger, fear, joy, sadness) best described the emotion expressed in the stimulus. The four alternatives were always visible and written in English and Krio on a sheet of paper. Participants' answers were verbally expressed and transcribed by the experimenter. Before each stimulus presentation the question "you able du am?" (i.e. "Are you ready?") appeared on the monitor, after the participant's affirmative answer the experimenter pressed the spacebar to show the successive stimulus. The behavioral experiment lasted approximately 15 min.

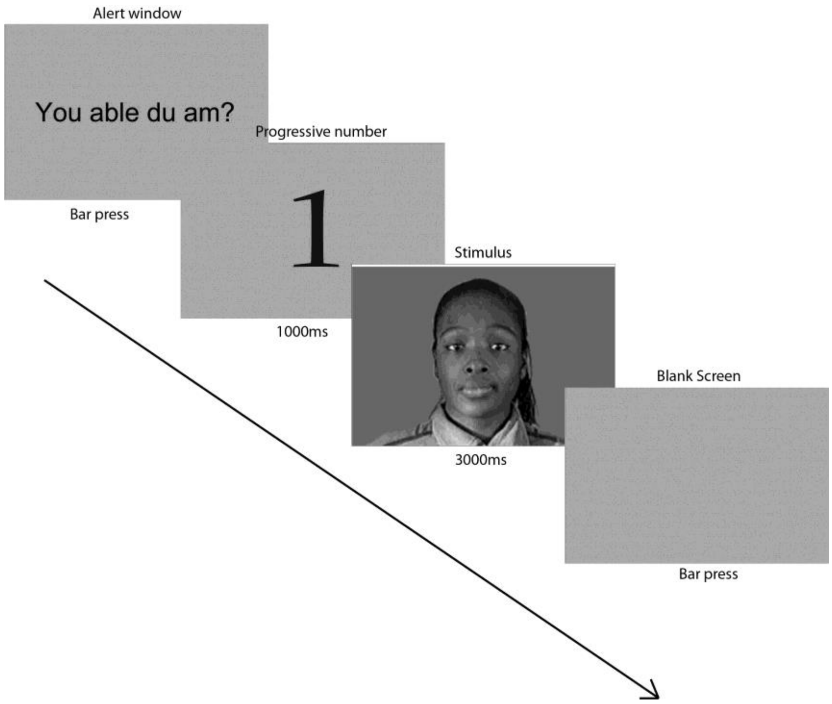

Figure 1 – Graphical representation of the behavioral experiment procedure.

Physiological experiment (Figure 2) **-** Participants were required to abstain from alcohol, caffeine and tobacco for 2 hours prior to the experiment. They sat comfortably at a table in front of a monitor (1024X768@75Hz). Participants were asked to carefully observe the videos. The physiological experiment consisted of four "condition-blocks" (each lasting 192 sec) and two "baseline-blocks" (each lasting 120 sec).

The four "condition-blocks", one for each emotional condition (anger, fear, joy and sadness), were randomly presented. Inside each "condition-block" the sixteen stimuli, comprising the same emotion, were randomly presented three times (48 trials). Each stimulus was preceded by a fixation cross lasting one second. The two "baseline-blocks", consisting of a black centered fixation cross on gray background, were performed one before (Baseline) and one after (Recovery) the four "condition-blocks". Overall the physiological experiment lasted 17 min. Electrophysiological responses were recorded for its entire duration. In order to maintain participants' attention, after each "condition-block" the experimenter posed a question about the videos just shown. Participants' faces were video-recorded to ensure that they looked at the screen.

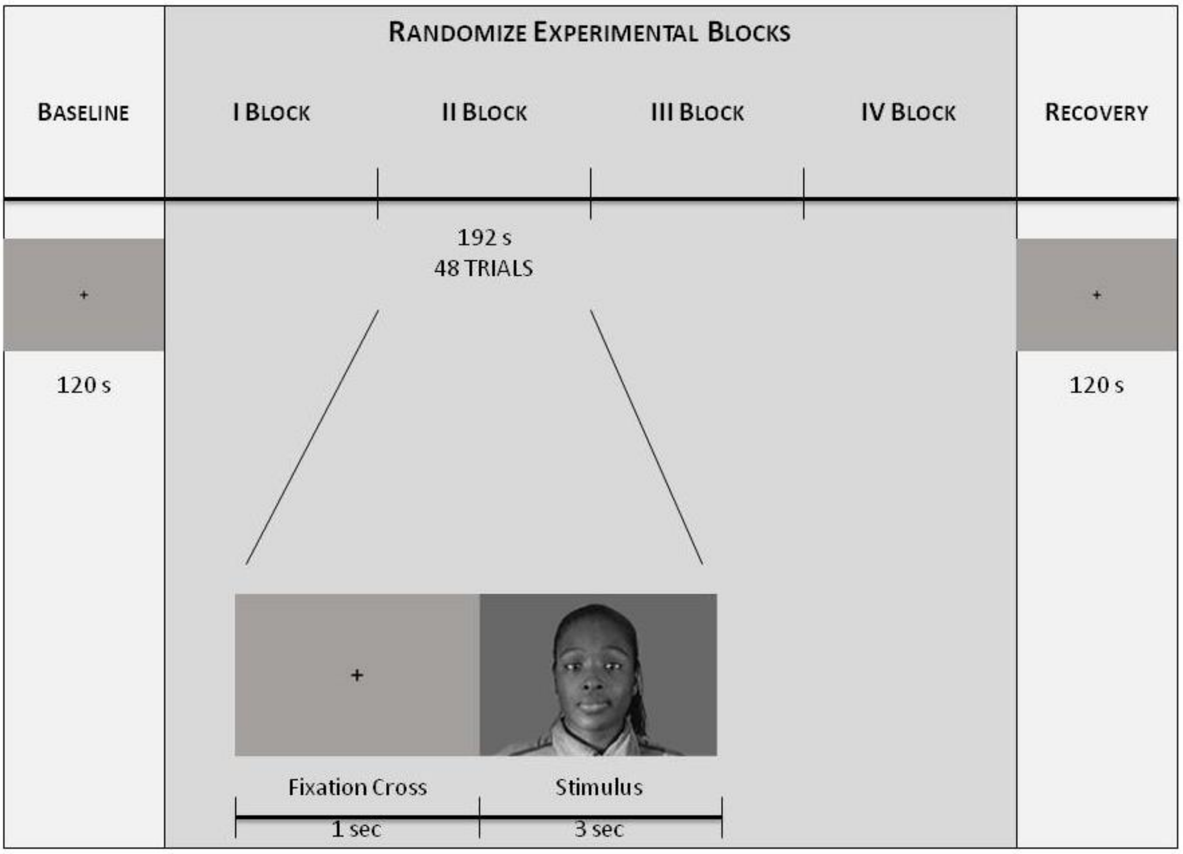

Figure 2 – Graphical representation of the physiological experiment procedure.

During the entire duration of the physiological experiment Facial EMG and RSA were recorded and subsequently extracted following the subsequent setting and procedures.

Facial EMG - Facial EMG activity was bipolarly recorded on the left side of the face with 4 mm standard Ag/Ag-Cl electrodes. Before being attached over the Corrugator Supercilii and the Zygomaticus Major muscle regions (Fridlund & Cacioppo, 1986) the electrodes were filled with gel electrode paste and the participants' skin was cleaned with an alcohol solution. Data were converted and amplified with an eight-channel amplifier (PowerLab8/30; ADInstruments UK) and displayed, stored, and reduced with LabChart 7.3.1 software package (ADInstruments, 2011). Facial EMG were sampled at 2 kHz and recorded with an online Mains Filter (adaptive 50 Hz filter). A 20–500 Hz band-pass filter (van Boxtel, 2001) was applied offline on the raw facial EMG signal. The average amplitude of the EMG signal was obtained with the root-mean-square method (Fridlund & Cacioppo, 1986). Following standard practice (Lang, Greenwald, Bradley, & Hamm, 1993; Winkielman & Cacioppo, 2001), EMG response (expressed in microvolts) was measured as change scores representing the difference between activity during each 500 msec of the 3 sec stimulus period and the 500 msec of the fixation cross immediately preceding stimulus onset. EMG signal and video recordings were visually inspected off line by the experimenters. In order to remove artifacts, EMG data that coincided with participants' contingent movements (e.g. coughing, talking or whole head movements) were excluded from the analysis. Moreover, trials with mean change scores that were 2 SD above or below the grand mean change score calculated for each participant were considered outliers and removed.

RSA - Three Ag/AgCl pre-gelled electrodes (ADInstruments, UK) with a contact area of 10 mm diameter were placed in an Einthoven's triangle configuration to monitor ECG (Powerlab and OctalBioAmp8/30, ADInstruments, UK). The ECG was sampled at 1 kHz and online filtered with the Mains Filter. The peak of the R-wave of the ECG was detected from each sequential heartbeat. The R-R intervals were extracted and the artifacts edited by integer division or summation (Berntson et al., 1997). Editing consisted of visual detection of outlier points, typically caused by failure to detect an R-peak (e.g., edit via division) or faulty detections of two or more ‘‘peaks’’ within a period representing the R-R interval (e.g., edit via summation) (Berntson et al., 1997). The amplitude of RSA was quantified with CMetX (available from http://apsychoserver.psych.arizona.edu) that produces data with a correlation near the unity with those obtained using Boher & Porges method (Allen et al., 2007). The amplitude of RSA [expressed in $\ln(\text{msec})^2$] was calculated as the variance of heart rate activity across the band of frequencies associated with spontaneous respiration (0.12–0.40 Hz) (Allen et al., 2007). RSA was extracted for the first 2 min of each “condition-block” and each “baseline-block”, according to guidelines (Berntson et al., 1997). Mean Baseline value was the mean of Baseline and Recovery RSA values. The RSA suppression value for each “condition block” was measured as a change of scores between the RSA of the “condition block” and the one of Mean Baseline.

Statistical analyses

Participants’ Accuracy rate and False-Alarms (FA) rates were computed from behavioral experiment performance. Accuracy rate was calculated as percentage of participants’ correct responses. False-Alarms rates were measured as percentage of incorrect use of each emotion label calculated considering each emotion separately (e.g., incorrect use of angry label during fear facial expression recognition).

To verify the presence of between groups differences in explicit facial expressions of emotions recognition, a repeated-measures ANOVA was performed on accuracy rate in forced-choice facial emotion recognition task with Group (SBg, Cg) as between-factor and Emotion (Anger, Fear, Joy, Sadness) as within-factor.

Moreover, the presence of an anger recognition bias was evaluated conducting four separate repeated-measures ANOVAs on FA rates considering Group (SBg, Cg) as between-factor and FA (3 levels) as within-factor.

To evaluate if the two groups of participants differed in their Facial EMG activations to different facial expressions of emotions a repeated-measures ANOVA was performed on facial EMG responses with Group (SBg, Cg) as between-factor and with Muscle (Corrugator, Zygomaticus), Emotion (Anger, Fear, Joy, Sadness) and Epoch (six epochs lasting 500 msec) as within-factors.

Whenever appropriate, significant differences between and within groups were explored performing LSD post-hoc comparisons.

Regarding RSA, four two-tailed t-tests with Bonferroni-corrected $p < 0.012$ (calculated as alpha level/number of comparisons = 0.05/4) were conducted on Baseline and Recovery RSA values. Five participants (two from the SBg and three from the Cg) were excluded from this analysis being outliers (±2 SD), thus the analysis on autonomic data concerned 17 street-boys and 19 controls. First, two independent sample t-tests were executed, comparing the two groups, on Baseline and Recovery RSA values. Secondly, being well known that during situations demanding sustained attention RSA decreases (S W Porges, 1995), two t-tests were performed comparing Baseline and Recovery RSA values of each group. If an attentional effect were present, Recovery should be significantly lower than Baseline.

Finally, in order to verify the existence of a significant correlation between Mean Baseline RSA and the levels of RSA suppression measured during the presentation of threatening stimuli, two correlation analyses (one for each group) were performed on Mean Baseline value and the RSA suppression values of each condition (M A Patriquin, Scarpa, Friedman, & Porges, 2011).

II.c Results

Behavioral Results

Accuracy rate – Repeated-measures ANOVA showed that the factor Group was significant ($F_{1,39}$ = 27.15 p<0.005) as was the factor Emotion ($F_{3,117}$ = 55.35 p<0.005), as well as the interaction of Emotion by Group ($F_{3,117}$ = 5.91 p<0.005). Post hoc analyses, revealed that SBg had lower accuracy rate than Cg (SBg: 62.17% SE 3.76; Cg: 79.05% SE 2.32, p<0.005), and that Joy was the most recognized emotion (98.48% SE 0.61) while Sadness was the less recognized one (45.73% SE 3.44). Joy and Sadness were, indeed, significantly different from all other emotions (all p_s<0.005). Post hoc analysis on the interaction Emotion by Group showed that the two groups differed in their accuracy rates to Fear (SBg: 51.97% SE 8.17, Cg: 84.09% SE 4.79) and Sadness (SBg: 31.91% SE 4.58, Cg: 57.67% SE 3.44) (all p_s<0.005). Within the SBg accuracy rates for each emotion differed from each other (all p_s<0.05), being Joy (97.37% SE 1.20) the most recognized emotion followed by Anger (67.43% SE 4.37), Fear (51.97% SE 8.17) and Sadness (31.91% SE 4.58). Within the Cg, Joy (99.43% SE 0.39) was the most recognized emotion followed by Fear (84.09% SE 4.79), Anger (75.00% SE 3.32) and Sadness (57.67% SE 3.34); the accuracy rates for Anger and Fear were not significantly different (p>0.05) (Figure 3).

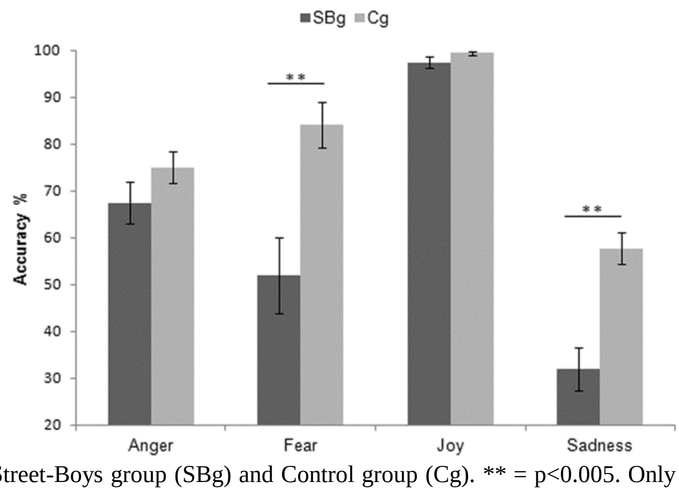

Figure 3 - Accuracy rate for Street-Boys group (SBg) and Control group (Cg). ** = p<0.005. Only differences between groups are shown. See text for differences inside each group. Error bars are SE. (Ardizzi et al., 2013)

False Alarms rate for anger emotion – Repeated-measures ANOVA demonstrated a non-significant effect of the factor group ($F_{1,39}$ = 1.96 p>0.05), however it showed a significant main effect of FA ($F_{2,78}$ = 23.18 p<0.005). The post hoc test on FA showed that the mistaken use of the three labels differed significantly from each other: sadness was the most used one (17.07% SE 1.99), followed by fear (9.15% SE 1.65) and joy (2.29% SE 0.64) (all p_s<0.005). Interaction FA by Group was not significant ($F_{2,78}$ = 0.04 p>0.05) (Figure 4 panel A).

False Alarms rate for fear emotion – Repeated-measures ANOVA revealed that the factor Group was significant ($F_{1,39} = 12.27$ $p<0.005$), as well as the factor FA ($F_{2,78} = 6.56$ $p<0.005$) and the interaction FA by Group ($F_{2,78} = 3.44$ $p<0.05$). The post hoc analysis on the two main effects revealed that SBg committed significantly more FA than the Cg (SBg: 16% SE 2.97; Cg: 5.30% SE 1.24; $p<0.005$), and that anger was the most attributed label, being significantly different from all others (16.92% SE 3.84; all $p_s<0.05$). The post hoc test of the interaction FA by Group revealed that the two groups differed only for the use of the anger label (SBg: 28.29% SE 6.73; Cg: 7.10% SE 3.00; $p<0.005$). Moreover, within the SBg anger differed from all other labels (all $p_s<0.005$), whereas inside the Cg labels were all used equally often (all $p_s>0.40$) (Figure 4 panel B).

False Alarms rate for sadness emotion – Repeated-measures ANOVA showed again a significant main effect of Group factor ($F_{1,39} = 20.87$ $p<0.005$), as well as of FA factor ($F_{2,78} = 40.22$ $p<0.005$) and of FA by Group interaction ($F_{2,78} = 8.91$ $p<0.005$). The post hoc on the main effect of Group revealed that SBg committed significantly more FA than the Cg (SBg: 22.70% SE 3.59; Cg: 14.10% SE 1.71; $p<0.005$). The post hoc on the main effect FA revealed that all labels differed among each other: anger was the most attributed one (35.82% SE 3.79), followed by fear (16.92% SE 2.12) and joy (1.52% SE 0.64) (all $p_s<0.005$). The post hoc on the interaction FA by Group showed that SBg attributed more often the label anger than the Cg (SBg: 49.67% SE 6.17; Cg: 23.86% SE 2.87; $p<0.005$). Within the SBg the wrong use of each label was different from the others (anger: 49.67% SE 6.17; fear: 15.46% SE 3.89; joy: 2.96% SE 1.30; all $p_s<0.05$). On the other hand, inside the Cg the incorrect attribution of joy differed from all other labels (0.28% SE 0.28 all $p_s<0.05$) being the less used one, while no differences were found between anger and fear ($p>0.24$) (Figure 4 panel C).

False Alarms rate for joy emotion – Finally, the same analysis conducted on Joy condition showed that neither the factor Group ($F_{1,39} = 3.00$ $p>0.05$), nor the factor FA ($F_{2,78} = 3.11$ $p>0.05$), nor the interaction FA by Group ($F_{2,78} = 2.22$ $p>0.05$) were significant (Figure 4 panel D).

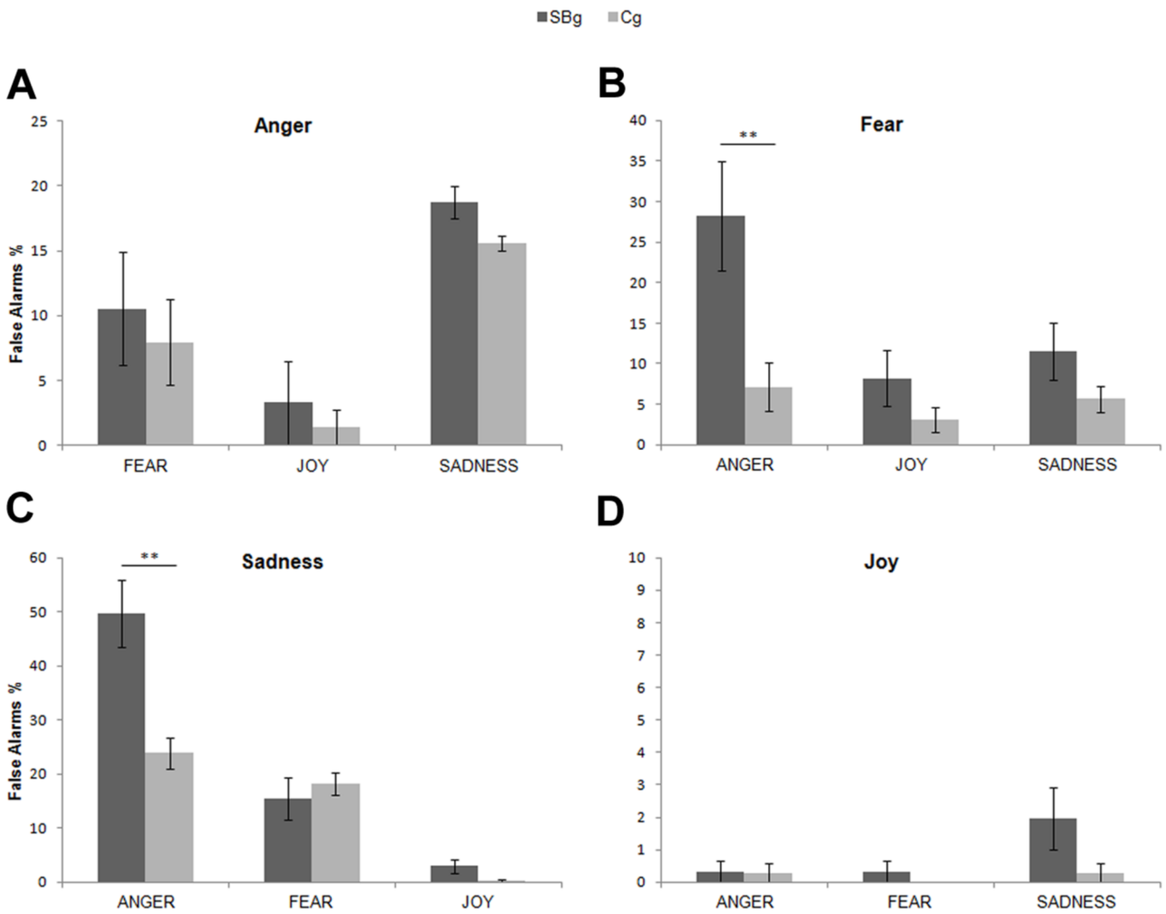

Figure 4 - False Alarms rate displayed condition by condition for Street-Boys group (SBg) and Control group (Cg). ** = p<0.005. Only differences between groups are shown. See text for differences inside each group. Error bars are SE. (Ardizzi et al., 2013)

Physiological Results

Facial EMG - The repeated-measures ANOVA revealed that the main effects of Group ($F_{1,39}$ = 24.84 p<0.005), Muscle ($F_{1,39}$ = 9.10 p<0.05) and Emotion ($F_{3,117}$ = 6.30 p<0.05) were significant as were the interactions Muscle by Emotion ($F_{3,117}$ = 22.00 p<0.005), Muscle by Emotion by Group ($F_{3,117}$ = 5.75 p<0.005), Emotion by Epoch ($F_{15,585}$ = 2.32 p<0.005) and the interaction Muscle by Emotion by Epoch ($F_{15,585}$ = 5.40 p<0.005). The post hoc test on the main effects of Group and Muscle showed that the SBg (−0.46 µV SE 0.03) had lower EMG responses than the Cg (0.15 µV SE 0.03) (p<0.005), and that the Corrugator muscle (−0.01 µV SE 0.02) was more activated than the Zygomaticus (−0.25 µV SE 0.03) (p<0.05). The post hoc on the main effect of Emotion revealed that Joy (0.10 µV SE 0.05) differed from all other emotions, showing the highest EMG responses (all p_s<0.05). The post hoc on the interaction Muscle by Emotion showed that the Corrugator responses during each emotion condition were significantly different from the Zygomaticus ones (all p_s<0.005), moreover within each muscle EMG response to Joy was different from all other activations, being the highest for the Zygomaticus (0.45 µV SE 0.09; all p_s<0.005) and the lowest for the Corrugator (−0.24 µV SE 0.02, all p_s<0.05).

Importantly, the post hoc conducted on the interaction Muscle by Emotion by Group showed that the Corrugator responses of the SBg during Anger, Fear and Sadness conditions were significantly lower than the respective Corrugator responses of the Cg (all p_s<0.05). Within the SBg the Corrugator responses during all emotions conditions were not significantly different (all p_s>0.42); otherwise, within the Cg the response during Joy condition was significantly different from the other conditions (all p_s<0.005) (Figure 5 panel A).

For the Zygomaticus, the response during Joy condition significantly differed between the two groups, being SBg responses lower than Cg ($p<0.005$). In both groups responses during Joy condition were significantly different from all other conditions (SBg all $p_s<0.05$; Cg all $p_s<0.005$) (Figure 5 panel B). The post hoc of the interaction Emotion by Epoch wasn't discussed because less informative than the following interaction lacking the significant factor Muscle. The post hoc of the interaction Muscle by Emotion by Epoch revealed that the two muscles activations, inside each emotion condition, were significantly different during the entire duration of the stimuli (all $p_s<0.005$). The Corrugator muscle did not show any significant difference among epochs for any emotion (all $p_s>0.06$). The lack of modulation among different epochs was also found for the Zygomaticus muscle for all negative emotions (Anger, Fear, Sadness), but not for Joy. In this condition Zygomaticus EMG signal in each epoch was different from all others excluding the firsts two (all $p_s<0.05$), with increasing EMG signal in relation with the intensity of the observed emotion.

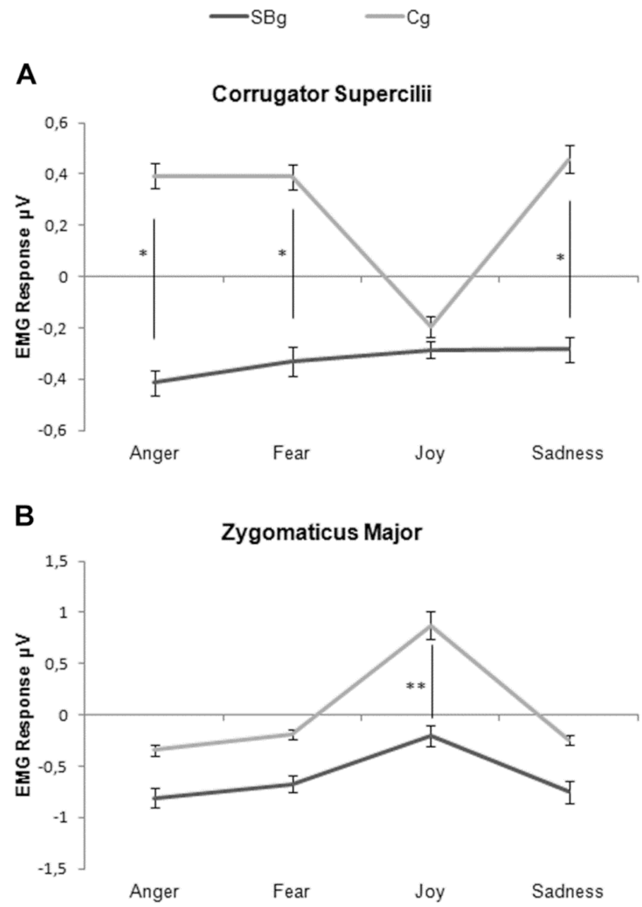

Figure 5 - Corrugator Supercilii (A) and Zygomaticus Major (B) EMG responses for Street-Boys group (SBg) and Control group (Cg) during presentation of emotional facial expressions. * = $p<0.05$; ** = $p<0.005$. Only differences between groups are shown. See text for differences inside each group. Error bars are SE. (Ardizzi et al., 2013)

Baseline and Recovery RSA values – Bonferroni corrected t-tests, comparing SBg and Cg values of Baseline and Recovery RSA, evidenced a significant between-groups difference only for Recovery RSA value (Baseline: $T_{34} = -1.07$, $p>0.05$; Recovery: $T_{34} = -2.72$, $p<0.012$) (Figure 6). The SBg (5.86 $ln(msec)^2$ 0.21) showed a lower RSA value during Recovery than Cg (6.53 $ln(msec)^2$ SE 0.16). No significant difference was found between Baseline and Recovery within SBg (Baseline: 6.04 $ln(msec)^2$ SE 0.25; Recovery: 5.86 $ln(msec)^2$ SE 0.19; $T_{16} = 1.31$, $p>0.05$) and Cg (Baseline: 6.36 $ln(msec)^2$ SE 0.18; Recovery: 6.53 $ln(msec)^2$ SE 0.16; $T_{19} = -1.59$, $p>0.05$) (Figure 6).

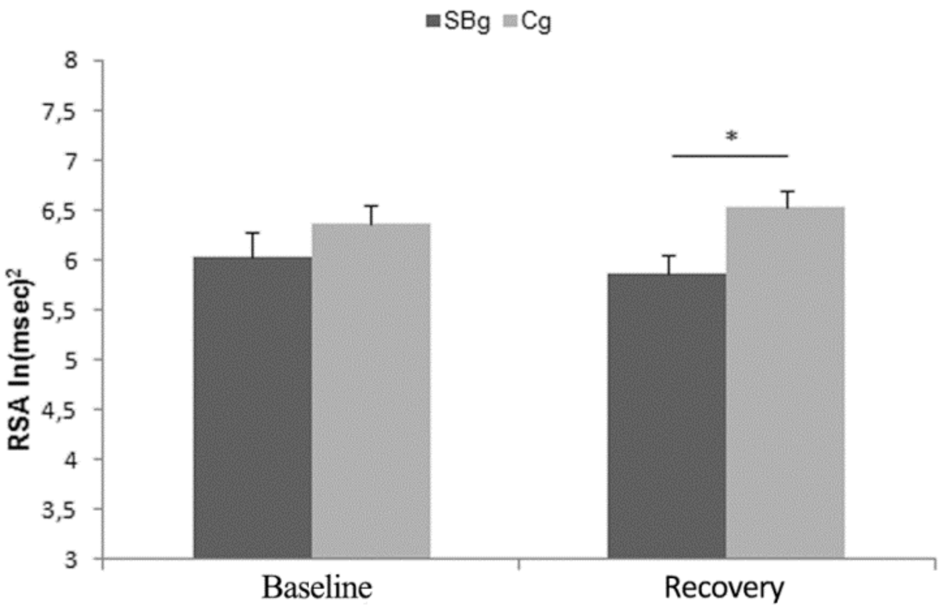

Figure 6 - Baseline and Recovery RSA values for Street-Boys group (SBg) and Control group (Cg). * = p<0.012. Error bars are SE. (Ardizzi et al., 2013)

RSA suppression - Correlation analyses demonstrated that SBg showed significant negative correlation in Fear ($r_{17} = -0.55$, $p<0.05$), Sadness ($r_{17} = -0.59$, $p<0.05$) and Joy ($r_{17} = -0.50$, $p<0.05$) but not in Anger ($r_{17} = -0.02$, $p>0.05$) conditions. Otherwise, as expected, we found a significant negative correlation in Anger condition only, for the Cg ($r_{19} = -0.49$, $p<0.05$) (Figure 7). In other words, among SBg higher Mean baseline RSA corresponded to higher RSA suppression during the visualization of Fear, Sadness and Joy facial expressions. Among Cg the same correlation was found only during Anger presentation.

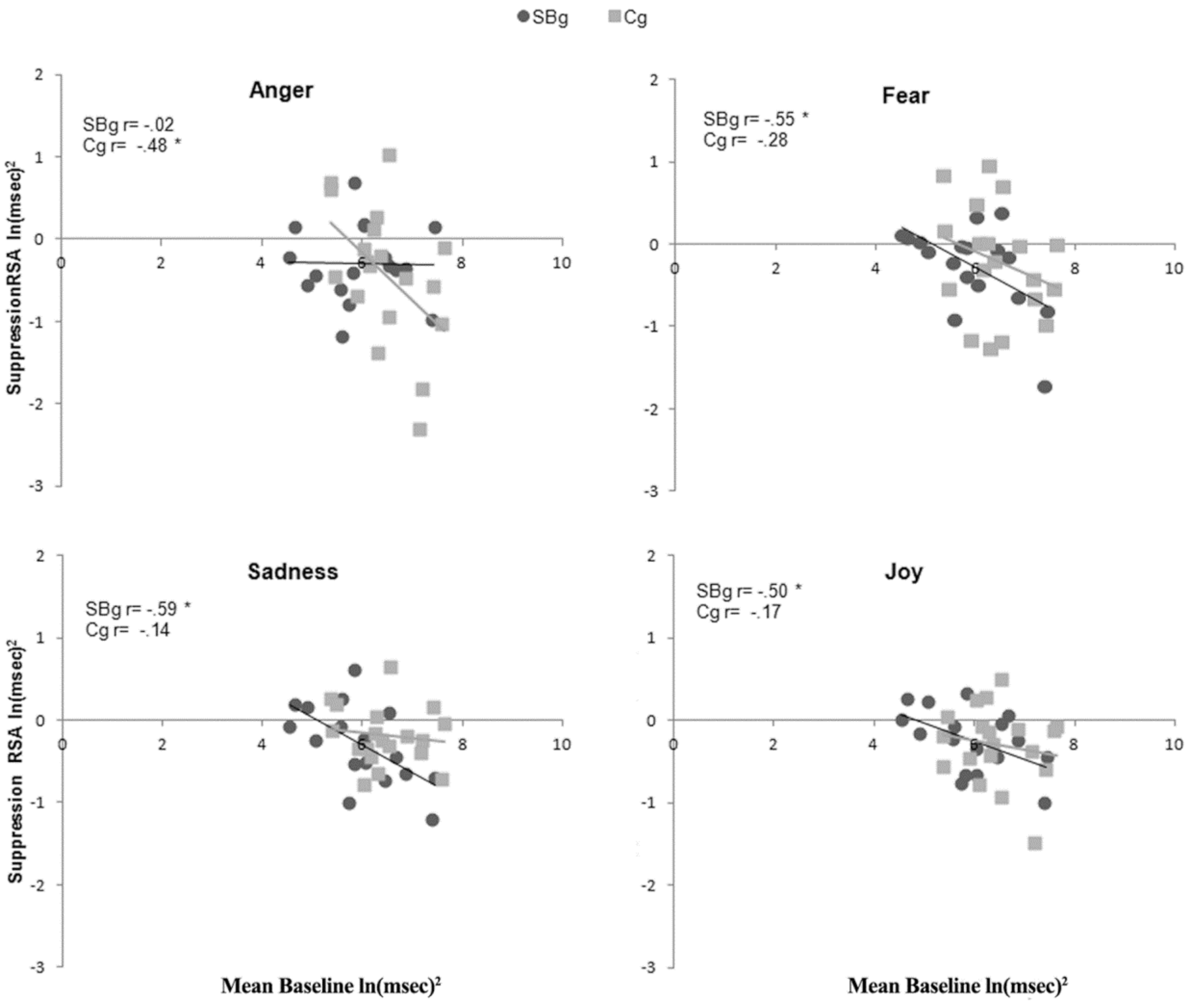

Figure 7 - Correlation between Mean Baseline and Suppression RSA values for Street-Boys group (SBg) and Control group (Cg) inside each condition. * = p<0.05. (Ardizzi et al., 2013)

II.d Discussion

The aim of the present study was to investigate if high levels of maltreatment and neglect could influence the explicit recognition of facial expressions of emotions, Facial Mimicry, and the related autonomic regulation of social behavior in a sample of Sierra Leonean street-boys. We included only male participants to exclude demonstrated gender-related differences (Seltzer et al., 2014). We evaluated, at a behavioral level, the presence of the well-known bias for angry facial expressions (Gibb et al., 2009; Pollak et al., 2000; Pollak & Kistler, 2002; Pollak & Sinha, 2002; Scrimin et al., 2009). SBg showed less accuracy than Cg in sadness and fear conditions, moreover the FA analysis revealed that SBg erroneously used anger label significantly more often than all other labels and with respect to Cg. In agreement with previous studies, our results confirmed that the exposure to high level of maltreatment and neglect induce among street-boys, but not among controls, a biased recognition of facial expressions of emotions favoring anger, to the detriment of the recognition of other negative facial expressions (i.e., fear and sadness). Given the ethno-cultural homogeneity of the two groups of participants, we can exclude that the described differences might be due to cultural bias.

At a physiological level the Facial Mimicry and autonomic responses to facial expressions of the SBg, manifested severe impairments. Congruent electromyographic responses (i.e., Corrugator activity for negative facial expressions and Zygomaticus activity for positive expressions) of street-boys resulted significantly weaker than those of controls. Furthermore, the Corrugator responses of street-boys did not show the habitual modulation for positive and negative stimuli (Dimberg, 1990; Fridlund & Cacioppo, 1986; Lang et al., 1993). Lower Corrugator EMG response during negative emotion was already found in women reporting high-betrayal abuse in childhood (Reichmann-Decker et al., 2009). Differing from our results, Reichmann-Decker et al. (2009) found stronger Zygomaticus responses during positive emotions with respect to control group. These authors interpreted this result as an attempt to cope with an hostile environment. As suggested in introduction (see Chapter II - paragraph II.a) it is possible that age and gender influence strategies adopted to cope with an adverse environment. Further researches will be required to shed light on this point. Lack of difference in Corrugator responses during observation of positive and negative emotions was described also among children suffering from Autism Spectrum Disorders (McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006), who coherently show deficits in empathic resonance (Baron-Cohen, 2010). To the best of our knowledge no previous study reported a similar effect in children or young adults with a past history of abuse or maltreatment. The unspecific activation of the Corrugator reported here among street-boys is unlikely due to simply and unspecific attentional effects. As demonstrated by previous studies, abused children manifest a behavioral bias to anger emotional stimuli caused by an alteration of perceptive and attentive mechanisms (Pollak, 2008). Granted this behavioral bias also among street-boys, if attention modulated the EMG activation, stronger Corrugator EMG responses to angry faces should have been found. We actually found the opposite. Taken together, the present results suggest that early traumatic experiences influence processes supporting empathy, emotional reciprocity and emotion recognition (Iacoboni, 2009; Niedenthal, 2007; Oberman et al., 2007).

The effects of early aversive experiences were not restricted to electrophysiological EMG responses. At the autonomic level controls showed significant higher Recovery RSA value than street-boys. These results suggest that the observation of facial expressions of emotions induces higher social predisposition (S W Porges, 2003a) in controls with respect to adolescents exposed to higher levels of maltreatment and neglect. The effects of early aversive experiences on basal vagal autonomic regulation were investigated among female adolescents exposed to child maltreatment, who exhibited lower baseline RSA than controls (Miskovic et al., 2009), and among adults showing a deficit in rapidly re-engaging vagal regulation immediately after mild exercise (Dale et al., 2009). Our results extended these previous data demonstrating that early experiences influence the abilities to recruit autonomic regulation levels promoting social communication, not simply at a baseline level (Miskovic et al., 2009), or after a non-social task (Dale et al., 2009), but also after exposure to social stimuli like the facial expressions of emotions, as our data clearly demonstrate. The failure of SBg to recruit autonomic regulation levels promoting social communication is coherent with the modulation of RSA during the visualization of facial expression of emotions. As expected, controls showed a significant correlation between Mean Baseline and RSA suppression during angry facial expressions visualization, suggesting an efficient vagal withdrawal (S W Porges, 2003b, 2007, 2009; J F Thayer & Lane, 2000) only in response to potentially threatening stimuli, like when observing angry facial expressions. On the contrary, street-boys showed a significant correlation between Mean Baseline and RSA suppression for non-threatening facial expressions (i.e., fear, sadness and joy) but not during the observation of angry faces. This suggests that street-boys interpreted fear, sadness and joy facial expressions as potentially threatening stimuli. This in turn led to the recruitment of the autonomic subsystem promoting defensive behaviors (fight/flight or immobilization), instead of the one enabling social communication and predisposition. In agreement with our results, previous studies demonstrated that when involved in interaction, children with abuse and maltreatment histories, manifested lower or incoherent RSA comparing to age matched children with no abuse or maltreatment past history(Oosterman, De Schipper, Fisher, Dozier, & Schuengel, 2010; Skowron, Cipriano-Essel, Gatzke-Kopp, Teti, & Ammerman, 2014). The absence of an effective suppression of the ‘‘vagal brake’’ during the observation of faces expressing anger could be likely due to a relatively low intensity of angry stimuli for individuals normally accustomed to more severe levels of anger expression as suggested by Pollak et al. (2005). It is possible that in order to perceive threat in angry faces and to rapidly predispose defensive responses, street-boys required more intense facial expressions of anger. Taken together, the present data demonstrate that street-boys not only showed impairment of facial emotion recognition and facial mimicry, but also of the autonomic regulation of social behaviors.

Limits

Street-boys lived in pervasive and perennial hostile conditions: they experienced physical violence from peers and adults, were abandoned by their family, they suffered high level of neglect, and at the moment of the experiment, they were serving a prison sentence. For these reasons street-boys could not be included in a single category of maltreatment (e.g. physical abuse, neglect, maltreatment) and the impact of the different traumatic experiences could not be established. Despite this lack of information, the involvement of participants with multiple forms of trauma might overcome some difficulties causing the divergent findings of many empirical studies focusing on single trauma experience (Hanson et al., 2014). Empirical designs focusing on samples exposed to single trauma type, although informative, result artificial, non-ecological and have many significant limitations including the lack of random assignment. Moreover, many variables (e.g., victims’ age, gender, socio-economics states, duration of trauma exposure, oppressor identity) could influence trauma effects and so require a rigorous experimental control, almost always not achieved. The involvement of participants exposed to multiple forms of trauma overcomes these problems. First, limitations related to unobserved or unmeasured characteristics of specific stressful experiences can be minimized. Second, the timing, chronicity, and scope of stress may differ greatly between groups; however, the end-state (dependent measures) could be similar across populations. Hence, working with multiple groups of children exposed to different forms of adversity has been suggested to be a fruitful way to overcome these limitations and has important advantages over past studies (Hanson et al., 2014).

Questionnaires evaluating cognitive and psychological aspects were not administered due to the lack of validated scales on this kind of sample.

Finally, to avoid gender influences only male participants were included in the experiments, so our conclusions can not be extended to females.

Conclusion

The present study demonstrates that early exposure to prolonged maltreatment and neglect not only influences the explicit recognition of facial expressions of emotions but also Facial Mimicry and vagal regulation responses. The environment in which street-boys lived likely promoted the suppression of emotional mimicry, building a wall between their and others' emotions. Alteration of empathy, emotional reciprocity and emotion recognition, normally fostered by processes like facial mimicry, could also influence the autonomic regulation of social behaviors, inducing lower social predisposition after the visualization of facial expressions and an ineffective recruitment of defensive behavior in response to nonthreatening expressions. These conclusions acquire further importance if we consider that accurate recognition and response to social emotional signals, like facial expressions, facilitate adaptive social functioning. Difficulties in affect recognition, reduced facial expressivity, blunted and deregulated RSA response are common characteristics also among clinical samples like children with autism (Bal et al., 2010; McIntosh et al., 2006) and antisocial personality disorder (Beauchaine et al., 2007; De Wied, van Boxtel, Posthumus, Goudena, & Matthys, 2009; Marsh & Blair, 2008). Failure of these processes can promote the development of antisocial behaviors and ineffective coping strategies. Such negative effects are amplified in a social context such as the one studied here, where high numbers of young boys live in conditions of extreme marginalization and maltreatment. Moreover, our findings confirm that in the case of exposure to early protracted traumatic experiences it would be necessary, besides the traditional attention to PTSD symptoms, also focusing on affective dysregulation, negative self-concept, and interpersonal problems as clinical report suggested (van der Kolk et al., 2009).

In this latter study adolescents exposed to protracted conditions of maltreatment and neglect were recruited. Further research should investigate if also among children suffering from similar conditions, explicit recognition, empathic understanding of others' emotion and self-regulation could be altered. In the case of protracted traumatic experiences, indeed, different victims' age correspond to different trauma duration as well as, different victims' development stage.

III.a Introduction

The empirical study described in the previous chapter, studying a population of Sierra Leonean street-boys, confirmed that protracted conditions of maltreatment and neglect induce specific alterations of the explicit recognition of facial expressions of emotions. Results evidenced that street-boys, but not controls, showed a bias for angry facial expressions recognition to the detriment of other negative facial expressions (i.e., fear and sadness facial expressions). These results were in agreement with the interpretation proposed by Pollak et al., (2005) who suggested that when exposed to maltreatment and neglect, environmental influences shape victims' developmental trajectories and adapt their pre-existing individual perceptual and attentive mechanisms to process environmental aspects that become especially salient (Pollak, 2008).

When addressing the explicit recognition of facial expressions of emotions, participants' age plays a fundamental role. In fact, it has been demonstrated that the recognition of emotional expressions gradually improves with age (Boyatzis et al., 1993; Herba & Phillips, 2004; Martínez-Castilla et al., 2014; Odom & Lemond, 1972; Philippot & Feldman, 1990). Even though very little is known about the continued development of emotion processing over the full childhood range into adolescence, a general consensus is present in considering infancy and childhood as periods marked by exuberant changes in brain growth and significant advances in social and emotional development (Silk et al., 2014). Behavioral studies demonstrated that emotional facial expressions recognition starts early in infancy and continues through childhood, adolescence, and adulthood (Herba & Phillips, 2004). An improvement in the perception of facial expressions was showed between the ages of 6 and 8 years, whereas little changes were evidenced until about 13 years, followed by a second improvement to adult performance at about 14 years (Kolb et al., 1992). Coherently, despite the precocious utilization of facial expressions, the neural processing involved in the perception of emotional faces develops in a staggered fashion throughout childhood, with the adult pattern appearing only late in adolescence (Batty & Taylor, 2006). There is broad agreement in considering joy as the first facial recognized expression (Herba & Phillips, 2004). Thereby, individuals first categorize expressions into superordinate categories of joy and non-joy and then distinguish the subordinate categories (Adolphs, 2002). So, if joy facial expression is compared with sadness, fear, anger, and disgust facial expressions, the negative ones are easily confused with each other, at a first stage of development (Adolphs, 2002). At a later stage, the categorization of negative facial expressions of emotions improves, with angry facial expression being first recognized first followed by sad and fear expressions (Herba & Phillips, 2004).

Overall, despite the normal development of emotion recognition over childhood period remains surprisingly under examined, it looks evident that children's age and development level are crucial variables that must be taken into account when focusing on emotions recognition. Furthermore, when addressing childhood trauma, victims' age plays a fundamental role, because it determines the level of development with which the traumatic events interfere (D'Andrea, Ford, Stolbach, Spinazzola, & van der Kolk, 2012). In agreement with this consideration, previous researches examined populations of abused or neglected children of different ages. Pollak et al., (2000) investigated facial expressions of emotions recognition in two samples of physically abused and neglected preschooler infants. Abused infants showed higher erroneous angry attribution (bias for angry facial expression) than age-matched individuals with no record of prior physical abuse trauma; neglected infants presented an overall greater difficulty in recognizing emotional expressions as well as fewer distinctions between emotions compared to the other two groups (Pollak et al., 2000). A perceptual and attentive bias for angry facial expressions was confirmed also among physically abused children above the age of 6 (Curtis & Cicchetti, 2011; Pollak & Kistler, 2002; Pollak et al., 2001, 2009; Pollak & Sinha, 2002; Pollak & Tolley-Schell, 2003). Other studies focused on post-institutionalized children who experienced severe neglect for their first two years of life prior to adoption into family environments. Internationally adopted post-institutionalized children, even tested at 4 years of age, presented difficulty identifying facial expressions of emotions. In addition, they had significant difficulties in matching appropriate facial expressions to happy, sad, and fearful scenarios. However, post-institutionalized children performed as controls when asked to identify and match angry facial expressions (Fries & Pollak, 2004). Similarly to what demonstrated among physically abused children, electrophysiological activities in response to angry faces of post-institutionalized children, seem to suggest higher sensitivity (i.e., higher P1 ERP component) to these stimuli, respect to age matched controls (Nelson et al., 2013).

The studies here briefly illustrated were all concentrated on repetitive and prolonged traumatic experiences of child physical abuse and neglect. The reported abuse cases occurred within the familiar environment and were perpetrated by victims' parents or relatives, suggesting the presence of a broad aversive milieu. In the case of neglect experiences, children lived for different periods in institution or orphanage sadly known for their very low level of affective care. Moreover, due to sampling procedure, the majority of reviewed works, engaged children after traumatic exposure. For example, post-institutionalized population was studied at the age of 4 and 8-year-old whereas the permanence in orphanage finished at the age of 2 (Fries & Pollak, 2004; Nelson et al., 2013).

The replication of the forced-choice facial expressions recognition task previously conducted on street-boys adolescent population, on a group of street-children allows to add additional fundamental information to the actual state of the art. First, it permits the examination of current high levels of both maltreatment and neglect in a children population. Among street-children the levels of maltreatment and neglect are particularly severe and occur outside familiar environment. International reports regarding street-children's life conditions highlight that they have limited access to basic resources (e.g., adequate food, shelter, clothing, and medical care) and that they act or suffer high levels of maltreatment, intimidation, robberies, and sexual or physical assaults in the street (Aptekar, 1994). It is evident that living in these conditions means to be exposed to both maltreatment and neglect, exacerbated by the absolute lack of a significant adult-care. The coexistence of both maltreatment and neglect experiences is relevant considering that also in other averse conditions a sharp distinction between different forms of childhood trauma (i.e., physical abuse, maltreatment, neglect) appeared to be more artificial than real. For example, episodes of physical abuse occurred among institutionalized population, as well as, neglect conditions could be lived by physically abused children. Studies of maltreating parents suggest that they show less positive and more negative emotions than non-abusive parents (Bugental, Blue, & Lewis, 1990; Kavanagh, Youngblade, Reid, & Fagot, 1988) but also that they tend to isolate themselves and to isolate their children from interaction with others, providing fewer non parental models of emotional communication (Salzinger, Feldman, Hammer, & Rosario, 1993). On the other hand, neglecting parents are less expressive and engaged with little exchange of affective information in inter-actions with their children and, thus, provide less support in learning to understand emotions more generally (Bousha & Twentyman, 1984). Similarly, institutional care is characterized by psychosocial deprivation and high peer-competition; sensory and cognitive stimulation are lacking, and high child-to-caregiver ratios (in some institutions, nearly 20:1) leave children with little social stimulation and almost no opportunity to form stable, emotional attachments to caregivers (Smyke et al., 2007; Zeanah et al., 2003). Second, the study of ongoing traumatic conditions instead of long-term effects on emotion recognition allows to investigate the eventual immediate adaptation of perceptive mechanisms before the impact of subsequent influences of other environmental factors. Following the interpretation proposed by Pollak et al., (2008), if the biased performance in explicit recognition of facial expressions of emotions is a consequence of the adaptation of children's functional perceptive mechanisms to aversive environment, it is especially during the exposure to these conditions that significant behavioral effects can be detected. Third, in the case of protracted traumatic experiences and especially among street-populations, different victims' ages correspond to different levels of trauma exposure. To replicate the same paradigm already employed with street-boys on a population of street-children could shed new light on the possible additive effects of exposure to protracted trauma during childhood and so guide further longitudinal researches.

In this context, it appears particularly interesting to extend previous researches conducted on adolescent sample, investigating the explicit recognition of facial expressions of emotions among children exposed to high level of prolonged and repetitive maltreatment and neglect. We expected to find a bias for angry facial expressions among street-children but not among controls. If a bias for anger was present this label should be over-attributed to other negative emotions (high level of Angry False Alarms). Both experimental populations were recorded at a developmental stage in which negative facial expressions could be scarcely recognized and so mixed-up. Thus, in principle a similar over-attribution trends could be expected in both populations. However, if the exposure to high levels of maltreatment and neglect induces specific adjustments in the recognition of facial expressions of emotions, the over-attribution of the anger label should be significantly more pronounced among street-children than among age-matched controls. Finally, putative impact of negative experiences impact on the explicit recognition of facial expressions must be independent from individual differences in naming skills.

III.b Method

Participants

A total of 64 participants were recruited for the study. Two participants were excluded from analyses due to difficulties in task execution, resulting in a final sample of 62 children. Of these 31 were street-children recruited directly in the street and in schools enrolling children without a family [STreet-children (STch) group; mean age 7.65 years SE 0.30; mean 2.55 years of schooling SE 0.24; 16 males] and 31 were children who had never been street-children, who lived with their parents or close relatives and who regularly attended to school [Control (Con) group; mean age 7.77 years SE 0.32; mean 2.45 years of schooling SE 0.23; 15 males]. The sample size exceeded the minimum amount required (n. 36) estimated by means of statistical power analysis (a priori sample size n. evaluated for 1-ß = 0.95, $\alpha = 0.05$ and effect size = 0.25). We suspended the sampling when we obtained two gender-balanced groups of enough size. All children belonging to STch group were homeless, they lived without a responsible adult and the street was their only source of basic needs (e.g., food, water, clothes, shelter). No significant differences were found between STch and Con groups either for age and years of schooling (Age: $t_{60} = 0.29$; $p = 0.77$; Years of schooling: $t_{60} = 0.30$; $p = 0.77$). Among street-children, 50% experienced physical violence and 18.6% fell victim of sexual violence, of these 22% had suffered both physical and sexual violence. Otherwise, 18.6% of children belonging to Con group were exposed to physical violence and nobody experienced sexual violence. All participants were literate, Temne (35.48%), Limba (22.58%) and Mende (16.13%) were the most frequent primary languages spoken.

In order to evaluate participants' cognitive performance and naming skills, Colored Progressive Matrices (CPM) (Raven, 1995) and Boston Naming Test (BNT) (Kaplan et al., 1983) were performed. CPM is a non-verbal test, measuring general cognitive abilities in terms of mental age, intellectual performance and non-verbal intelligence, designed for children aged $5^{1/2}$ through $11^{1/2}$ years of age. CPM requires non-verbal multiple choice responses to three sets of twelve matrices presented on a colored background. As described in the previous chapter (See Chapter II - paragraph II.b), BNT assesses visual naming ability and word retrieval. Tests choice was influenced by the lack of assessment instruments validated and applicable to African, and particularly Sierra Leonean, young population. Among tests evaluating cognitive performance, CPM was selected because, although not validated, normative values are reported in literature as it was already extensively used across a wide variety of settings in Africa (for a review see Lynn & Meisenberg, 2010). Moreover, BNT was chosen thanks to its quick and easy administration and because it is translated in many languages and commonly used in many countries.

Procedure

The experimental procedure consisted of the same forced-choice emotion recognition task derived from Ardizzi et al. (2013) and extensively described in the previous chapter (See Chapter II – paragraph II.b, Procedure sub-session). Briefly, participants were asked to verbally identify which of the four alternative labels (anger, fear, joy, sadness) best described the facial expression of emotion depicted in the stimulus. Stimuli were 64 video-morphing, lasting 3 seconds, showing the transition from a neutral to an emotional facial expression (i.e., anger, fear, joy, sadness) (Ardizzi et al., 2013; Umiltà et al., 2013). The entire experimental procedure lasted about 15 minutes.

Statistical data analyses

In order to assess possible between-group differences in cognitive performance and naming skill, two independent-sample t-tests (two-tailed) were performed comparing the average scores of STch and Con groups in CPM and BNT. A putative significant between-group difference in naming skill was better investigated evaluating if BNT scores were mediated by participants' age, cognitive performance or educational level. Age, CPM score and years of schooling were included as predictors in two hierarchical regression analyses (forward stepping), conducted independently for STch and Con group, with BNT score as dependent variable.

The presence of a recognition bias for angry facial expressions was assessed conducting a series of ANCOVAs separately on participants' Tendency rate (Ten; percentage use of each emotion label regardless of accuracy), General false alarm rate (Gfa; percentage of incorrect use of each emotion label), Emotion false alarm rate (Efa; percentage of incorrect use of each emotion label calculated considering each emotion separately) and Accuracy rate (Acc; percentage of correct use of each emotion label). For each ANCOVA Group (STch, Con) was entered as between-factor; Emotion (anger, fear, joy and sadness; or three of them in Efa analyses) as within-factor. BNT score, CPM score, years of schooling and age were entered as covariates.

Accordingly to guidelines (Girden, 1992), when the sphericity assumption was violated, Geisser–Greenhouse correction was calculated and adjusted df, corrected p values, and epsilon values (ε) were reported. Whenever appropriated, significant between and within groups differences were explored performing Bonferroni corrected t-tests (two-tailed). Partial eta square (η^2_p) was calculated as effect size measure. The significant effect of covariate was evaluated by coherent linear regression analyses.

III.c Results

Cognitive performance and naming skill

No significant between-groups difference was found in CPM score (STch: 18.06 SE 0.70; Con: 17.97 SE 0.71; $t_{60} = 0.097$; $p = 0.92$). Otherwise, significant between-groups difference was evidenced in BNT score (STch: 11.03 SE 0.75; Con: 15.84 SE 1.17; $t_{60} = -3.46$; $p < 0.005$).

Regression analysis conducted on BNT score of STch group ($R^2 = 0.30$; $F_{(1,29)} = 12.51$; $p < 0.005$) demonstrated that Age was the only significant predictor ($t = 3.54$, $\beta = 0.55$, $p < 0.005$).

The same regression analysis conducted for Con group ($R^2 = 0.48$; $F_{(1,29)} = 26.47$; $p < 0.001$) revealed that BNT performance was explained only by years of schooling ($t = 5.15$, $\beta = 0.69$, $p < 0.001$).

Response tendency

Mauchly's test conducted on Ten indicated that the assumption of sphericity had been violated ($\chi^2_{(5)} = 71.15$, $p < 0.001$), therefore degrees of freedom were adjusted using Greenhouse-Geisser correction ($\mathcal{E} = 0.63$). The ANCOVA conducted on Ten revealed that the factor Emotion was significant ($F_{1.9,105.3} = 3.98$; $p < 0.05$; $\eta^2_p = 0.07$), as well as the interaction of Emotion by Group ($F_{1.9,105.3} = 5.55$; $p < 0.005$; $\eta^2_p = 0.09$) (Figure 8). Bonferroni corrected t-tests (with α 0.05 = 0.005) conducted on Emotion by Group interaction revealed that STch group used significantly more frequently the label anger than all other labels (anger VS fear: $t_{60} = 26.57$, $p < 0.0001$; anger VS joy: $t_{60} = 17.78$, $p < 0.0001$; anger VS sadness: $t_{60} = 47.25$, $p < 0.0001$), whereas Con group used that label more frequently only with respect to the other negative labels (anger VS fear: $t_{60} = 5.20$, $p < 0.0001$; anger VS joy: $t_{60} = -1.28$, $p = 0.21$; anger VS sadness: $t_{60} = 11.55$, $p < 0.0001$) Furthermore, comparing the two groups, STch group used significantly more frequently the labels anger (STch VS Con:$t_{60} = 16.42$, $p < 0.0001$) and joy (STch VS Con:$t_{60} = 6.64$, $p < 0.0001$), and significantly less frequently the labels fear (STch VS Con:$t_{60} = -4.79$, $p < 0.0001$) and sadness (STch VS Con:$t_{60} = -20.72$, $p < 0.0001$) than Con group.

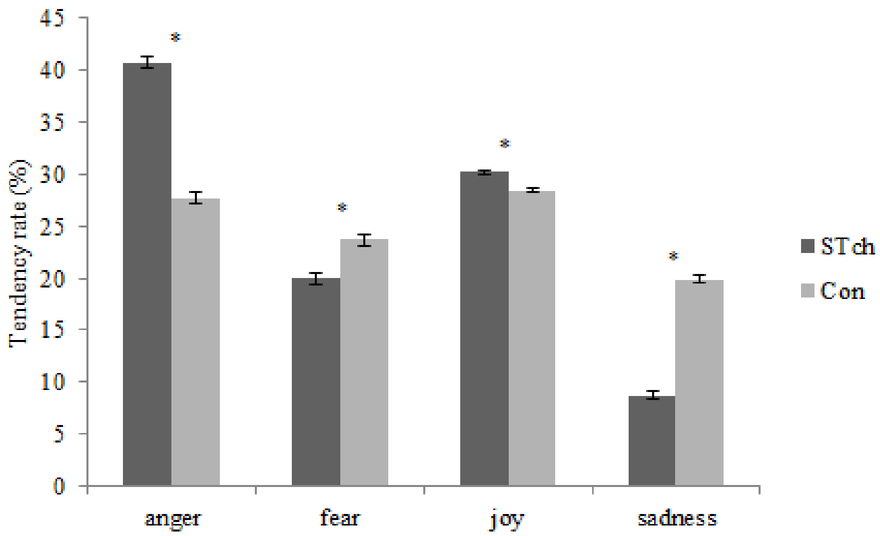

Figure 8: Response Tendency rate (Ten %) for Street-children group (STch) and Control group (Con). * = p < 0.005. Only between groups differences are shown. For differences within groups, see text. Error bars represent SE.

General False alarm

Mauchly's test conducted on Gfa identified a sphericity violation ($\chi^2_{(5)} = 38.64$, $p < 0.0001$), hence degrees of freedom were adjusted using Greenhouse-Geisser correction ($\mathcal{E} = 0.68$). ANCOVA performed on Gfa revealed the significant effects of Group ($F_{1,56} = 11.96$ $p < 0.005$; $\eta^2_p = 0.18$) and of Emotion by Group interaction ($F_{2,114.90} = 5.378$ $p < 0.005$; $\eta^2_p = 0.09$) (Figure 9). Moreover, the CPM score, entered as covariate, resulted significant ($F_{1,56} = 8.24$ $p < 0.05$; $\eta^2_p = 0.13$), as well as the interaction Group by CPM score ($F_{2,53} = 3.74$ $p < 0.05$; $\eta^2_p = 0.12$). Bonferroni corrected t-tests (with α 0.05 = 0.004) performed on the main effect of Group showed that STch group (10.56 % SE 0.08) had a significantly higher Gfa frequency than Con Group (8.30 % SE 0.08) ($t_{60} = 20.62$, $p < 0.0001$). Bonferroni corrected t-tests performed on the interaction Emotion by Group revealed that the wrongly use of the anger label was more frequent than the incorrect use of all other emotion labels both for STch group (anger VS fear: $t_{60} = 26.88$, $p < 0.0001$; anger VS joy: $t_{60} = 39.02$, $p < 0.0001$; anger VS sadness: $t_{60} = 38.68$, $p < 0.0001$) and Con group (anger VS fear: $t_{60} = 6.18$, $p < 0.0001$; anger VS joy: $t_{60} = 19.11$, $p < 0.0001$; anger VS sadness: $t_{60} = 5.39$, $p < 0.0001$). Despite this similar trend, the two groups presented a significantly different rate in the mistaken use of anger, joy and sadness labels. Bonferroni corrected t-tests showed that STch group used more frequently the labels anger (STch VS Con:$t_{60} = 19.47$, $p < 0.0001$) and joy (STch VS Con:$t_{60} = 8.56$, $p < 0.0001$), and less frequently the label sadness (STch VS Con:$t_{60} = -4.53$, $p < 0.0001$) than Con group.

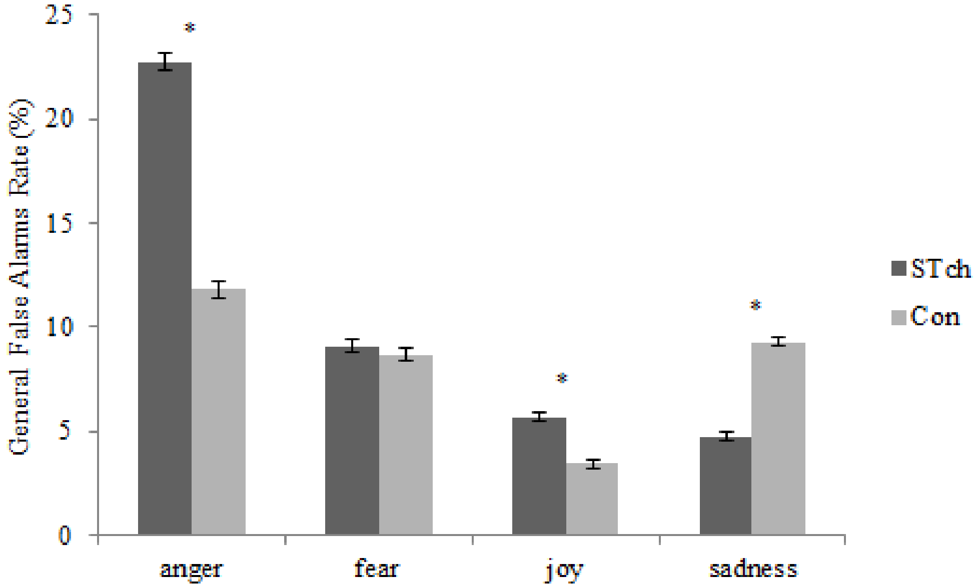

Figure 9: General false alarms rate (Gfa %) for Street-children group (STch) and Control group (Con). * = p < 0.004. Only differences between groups are shown. For differences inside each group, see text. Error bars represent SE.

To investigate the significant interaction Group by CPM score two linear regressions were conducted, separately for the two experimental groups, using average Global False Alarm rate as dependent variable and CPM score as predictor (Figure 10). Regression analyses conducted on STch group (R^2= 0.21; $F_{(1,29)}$ = 7.81; $p < 0.05$) and Con group (R^2= 0.22; $F_{(1,29)}$ = 8; $p < 0.05$) demonstrated that, in both groups, CPM score inversely predicts the average Global False Alarm rate (STch: t = -2.79, β = -0.46, 95% CI = -0.43 to -0.07, $p < 0.05$; Con: t = -2.83, β = -0.46, 95% CI = -0.57 to -0.09, $p < 0.05$). The regression coefficients of the two groups resulted not significantly different, as reflected by their CIs.

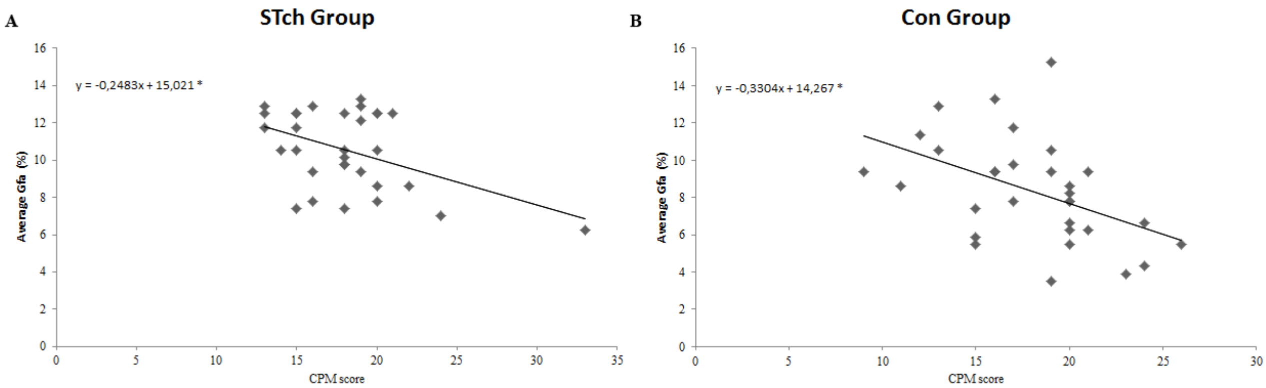

Figure 10: Plots of CMP score versus Average Gfa (%) for STch (panel A) and Con (panel B) Groups. Average Gfa = Average General False Alarms rate; STch Group = Street-children Group; Con Group = Control Group. * = $p < 0.05$.

Emotion False alarms

Efa rate for Anger emotion - ANCOVA performed for Anger emotion revealed a significant interaction Emotion by BNT score. Three linear regressions analyses (Figure 11) were conducted, separately for each emotion label, using the relative Emotion False Alarms rate as dependent variable and the BNT score as predictor. The BNT score, obtained by all participants, regardless of group membership, predicts the erroneous use of sadness label during angry facial expression recognition (R^2= 0.22; $F_{(1,60)}$ = 16.95; $p < 0.001$; t = 4.12, β = 0.47, 95% CI = 0.25 to 0.72; $p < 0.001$). On the contrary, the erroneous uses of fear (R^2= 0.03; $F_{(1,60)}$ = 2.14; 95% CI = -0.45 to 0.07; p = 0.15) and joy (R^2= 0.001; $F_{(1,60)}$ = 0.06; 95% CI = -0.07 to 0.05; p = 0.81) labels were not predicted by participants' BNT score.

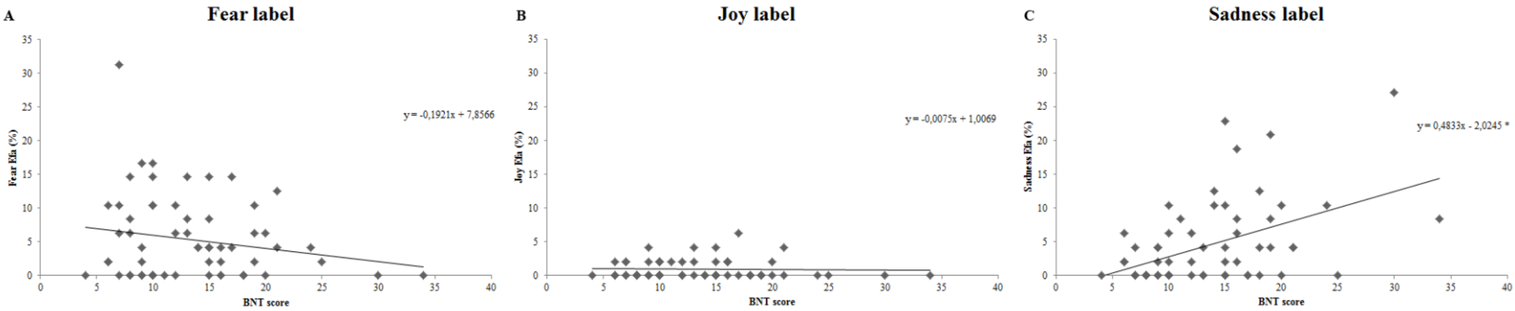

Figure 11: Plots of participants' BNT score versus Fear Efa (panel A), Joy Efa (panel B) and Sadness Efa (panel C). Efa = Emotion False Alarms rate. * = $p < 0.05$

Efa rate for Fear emotion – ANCOVA conducted for fear emotion revealed a significant interaction Emotion by Group ($F_{2,112} = 5.90$ $p < 0.005$; $\eta^2_p = 0.09$) (Figure 12). Moreover, CPM score entered as covariate, resulted significant ($F_{1,56} = 4.38$ $p < 0.05$; $\eta^2_p = 0.07$).Bonferroni corrected t-tests (with α 0.05 = 0.007) performed on the interaction Emotion by Group showed that, considering the STch group, the incorrect use of anger label was significantly higher when compared with the mistaken use of the other two possible wrong answers (anger VS joy: $t_{60} = 12.47$, $p < 0.0001$; anger VS sadness: $t_{60} = 19.56$, $p < 0.0001$). Differently, inside Con group, the use of the anger label resulted significantly lower with respect to the inaccurate use of sadness emotion label (anger VS sadness: $t_{60} = -8.84$, $p < 0.0001$). Comparing the mistaken performance of the two groups during fear facial expressions recognition, Bonferroni corrected t-tests evidenced that STch group used more frequently anger (STch VS Con:$t_{60} = 15.81$, $p < 0.0001$) and joy labels (STch VS Con:$t_{60} = 7.73$, $p < 0.0001$), and less frequently sadness label (STch VS Con:$t_{60} = -12.45$, $p < 0.0001$) than the Con group.

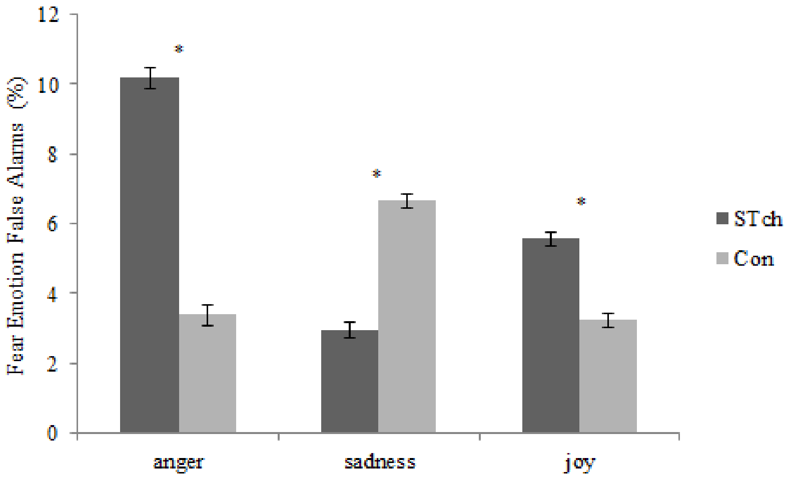

Figure 12: Fear Emotion false alarms (Efa %) for street-children group (STch) and Control group (Con). * = p<0.007. Only differences between groups are shown. For differences inside each group, see text. Error bars represent SE.

To investigate the significant effect of CPM score a linear regressions (Figure 13) was conducted using the average Efa rate for fear emotion as dependent variable and participants' CPM score as predictor. Regression analysis demonstrated that regardless of group membership, CPM score inversely predicted the average Efa rate for fear emotion ($R^2 = 0.13$; $F_{(1,60)} = 8.88$; $p < 0.005$; $t = -2.98$, $\beta = -0.36$, 95% CI = -0.63 to -0.12; $p < 0.005$).

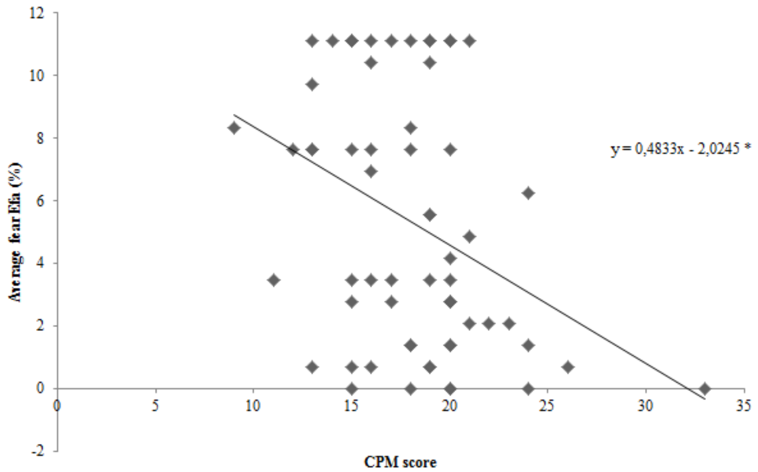

Figure 13: Plot of participants' CPM score versus Average Fear Efa. Efa = Emotion False Alarms rate. * = p < 0.05.

Efa rate for Sadness emotion – Mauchly's test conducted on Efa for Sadness emotion showed a violation of sphericity assumption ($\chi^2_{(2)}$ = 54,40, p< 0.001), therefore degrees of freedom were adjusted following Greenhouse-Geisser correction (Ɛ = 0.61). ANCOVA executed on the erroneous recognition of sadness revealed that the factor Group ($F_{1,56}$ = 15.60 p < 0.0001; η^2_p = 0.22) and the factor Emotion were significant ($F_{1.2,68.79}$ = 5.04 p < 0.05; η^2_p = 0.08), as well as the interaction Emotion by Group ($F_{1.2, 68.79}$ = 3.80 p < 0.05; η^2_p = 0.06) (Figure 14). Bonferroni corrected t-tests (with α 0.05 = 0.006) performed on the main effect of Group showed that STch group (9.26 % SE 0.09) had a significantly higher Efa rate than Con Group (6.33 % SE 0.09) (t_{60} = 23.55, p < 0.0001). Bonferroni corrected t-tests executed on the interaction Emotion by Group showed that both STch (anger VS fear: t_{60} = 34.81, p < 0.0001; anger VS joy: t_{60} = 59.42, p < 0.0001) and Con groups (anger VS fear: t_{60} = 15.65, p < 0.0001; anger VS joy: t_{60} = 37.19, p < 0.0001) erroneously used anger label significantly more frequently than the other two possible wrong labels. Comparing the mistaken performance of the two groups, Bonferroni corrected t-tests demonstrated that STch group used more frequently the label anger (STch VS Con:t_{60} = 17.57, p < 0.0001) and joy (STch VS Con:t_{60} = 7.24, p < 0.0001) than the Con group. No significant difference was found for the mistaken use of fear label (STch VS Con:t_{60} = 0.04, p = 0.97).

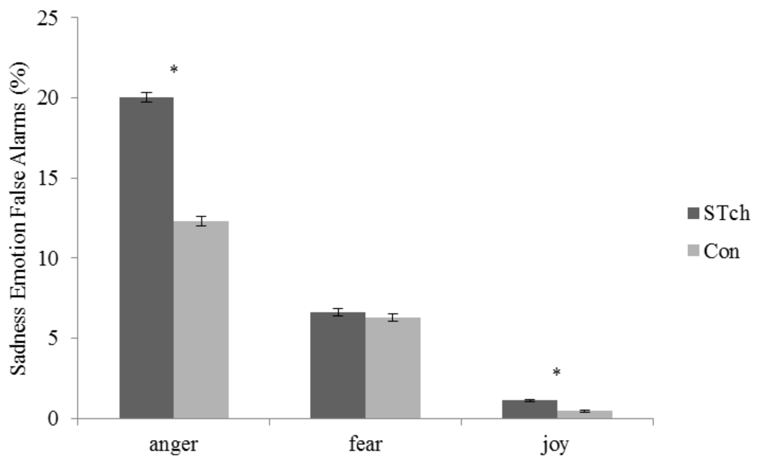

Figure 14: Sadness Emotion false alarms (Efa %) for street-children group (STch) and Control group (Con). * = p<0.006. Only differences between groups are shown. For differences inside each group, see text. Error bars represent SE.

Accuracy rate

Mauchly's test conducted on Acc showed a violation of sphericity assumption ($\chi^2_{(5)}$ = 75.95, p< 0.001), hence degrees of freedom were adjusted using Greenhouse-Geisser correction (Ɛ = 0.67). ANCOVA executed on Acc revealed a significant effect of the factors Group ($F_{1,56}$ = 12.71 p < 0.005; η^2_p = 0.18) and Emotion ($F_{2.02,112.96}$ = 10.47 p < 0.0001; η^2_p = 0.16), as well as of the interaction of Emotion by Group ($F_{2.02,112.96}$ = 4.37 p < 0.05; η^2_p = 0.7) (Figure 15). Moreover, CPM score ($F_{1,56}$ = 9.33 p < 0.005; η^2_p = 0.14) and the interaction Group by CPM score resulted significant ($F_{2,53}$ = 4.29 p < 0.05; η^2_p = 0.14). Bonferroni corrected t-tests (with α 0.05 = 0.004) performed on the main effect of Group showed that STch group (57.35 % SE 0.30) had significantly lower Acc rate than Con Group (66.49 % SE 0.30) (t_{60} = -21.25, p < 0.0001). Moreover, Bonferroni corrected t-tests executed on the interaction Emotion by Group revealed that, considering the STch group, anger was significantly better recognized than sadness and fear facial expressions, but less identified than joy facial expressions (anger VS fear: t_{60} = 19.65, p < 0.0001; anger VS joy: t_{60} = -30.70, p < 0.0001; anger VS sadness: t_{60} = 48.59, p < 0.0001). In the case of Con group, angry facial expressions were better recognized only than sadness facial expressions, and less identified than joy expressions (anger VS fear: t_{60} = 2.76, p = 0.007; anger VS joy: t_{60} = -41.99, p < 0.0001; anger VS sadness: t_{60} = 18.40, p < 0.0001). Comparing the two groups, STch group recognized significantly less the facial expressions of fear (STch VS Con:t_{60} = -10.04, p < 0.0001) and sadness (STch VS Con:t_{60} = -24.44, p < 0.0001) but significantly more angry facial expressions (STch VS Con:t_{60} = 6.79, p < 0.0001) than Con group.

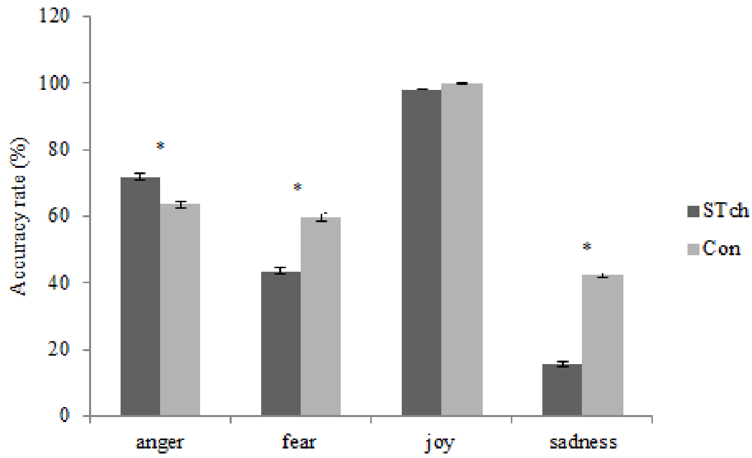

Figure 15: Accuracy rate (Acc %) for Street-children group (STch) and Control group (Con). * = p < 0.004. Only differences between groups are shown. For differences inside each group, see text. Error bars represent SE.

To investigate the significant interaction Group by CPM score two linear regressions were conducted (Figure 16), separately for the two experimental groups, using the average Accuracy rate as dependent variable and the CPM score as predictor. Regression analyses demonstrated that CPM score directly predicts the average Accuracy rate of both STch (R^2= 0.24; $F_{(1,29)}$ = 9.26; $p < 0.05$; t = 3.04, β = 0.49, 95% CI = 0.35 to 1.77; $p < 0.05$) and Con groups (R^2= 0.23; $F_{(1,29)}$ = 8.54; $p < 0.05$; t = 2.92, β = 0.48, 95% CI = 0.40 to 2.29, $p < 0.05$). The regression coefficients of the two groups resulted not significantly different, as reflected by their CIs.

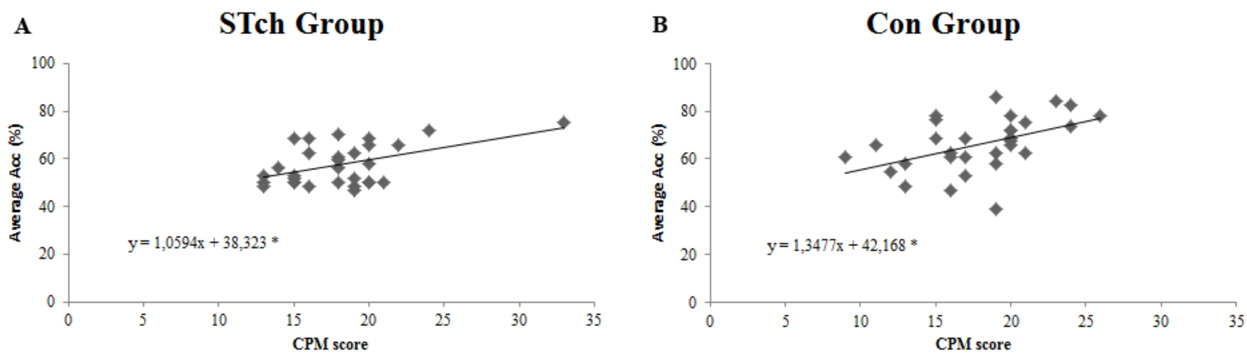

Figure 16: Plots of CMP score versus Average Acc (%) for STch (panel A) and Con (panel B) Groups. Average Acc = Average Accuracy rate; STch Group = Street-children Group; Con Group = Control Group. * = p < 0.05.

III.d Discussion

The aim of the present study was to investigate the effect of high levels of maltreatment and neglect on children's explicit recognition of facial expressions of emotions. Two groups of children performed a forced-choice facial expressions recognition task. One group was composed by street-children exposed to early adverse experience of maltreatment and neglect, whereas the second group consisted of age-matched control children. Results demonstrated that both groups tended to use anger label more frequently than all other alternative labels and, consequently, to over-attribute anger label to other negative emotions when incorrectly recognized. This over-attribution of anger was significantly more pronounced among street-children than among control participants. In fact, the analyses conducted on Tendency rate and General False Alarms rate, demonstrated that in both cases Street-children used the anger label significantly more frequently with respect to controls. Moreover, Emotion False Alarms investigations evidenced that street-children showed an over-attribution of anger both to fear and sadness facial expressions, whereas controls exhibited that tendency only for sadness facial expression. Consequently, controls when incorrectly recognized fear facial expressions, they over-attributed the sadness label instead of the anger label. As expected, these response patterns contributed to a significantly lower street-children's Accuracy rate in sadness and fear recognition, and to a higher street-children's accuracy rate in anger recognition with respect to controls.

Results demonstrated that prolonged exposure to maltreatment and neglect during childhood, similarly to what happened in the adolescent sample previously investigated with the same task (Ardizzi et al., 2013), induces among children a specific alteration of emotion recognition processes, under which facial expressions of negative emotions are wrongly recognized as angry facial expression. This similar pattern of results suggests, at least for explicit bias in the recognition of angry facial expressions, a minimal effect of trauma exposure. This hypothesis requires specific longitudinal studies to be confirmed, but this initial conclusions appears to be coherent with an empirical study showing bias in the recognition of angry facial expressions also after single trauma exposure (Scrimin et al., 2009).

The presence of a similar, tough minor, tendency to use anger label among control children confirms the relevant interplay between victims' age and traumatic events (D'Andrea et al., 2012). These findings could be explained by results of studies demonstrating that individuals first categorize expressions into superordinate categories of joy and non-joy and then distinguish the subordinate categories. When joy facial expressions are compared with different negative expressions (e.g., sadness, fear, anger, and disgust), the negative ones are easily confused with each other (Adolphs, 2002). At a later stage, also the categorization of negative facial expressions become more accurate generally starting from angry facial expression followed by sadness and fear expressions (Herba & Phillips, 2004). A rigorous investigation of false alarms distribution across age during erroneous recognition of facial expressions is still lacking, however, we can hypothesize that at least at an initial developmental stage, in response to an unclear negative facial expression, children tend to attribute the most salient and better recognized negative emotion, that is anger. Our data suggest that exposure to maltreating and neglectful environment during childhood alters the normal development of the recognition of facial expressions of emotions, worsening children's bias towards the identification of specific negative facial expressions.

Although participants' naming skills and cognitive performance, measured by BNT score and CPM score respectively, influenced task performance, the bias for the recognition of angry facial expressions was not justified either by that variables or by participants' educational level and age. As could be expected, participants' cognitive performance, regardless of group membership, significantly predicted the global task performance (i.e., average Accuracy rate and average General False Alarms rate). Intellectual functioning plays a key role in accurately identifying expressions of affect (Anderson & Miller, 1998), most likely because it measures fluid and crystallized abilities that are shaped by both neurological development and prior learning experiences (Horn & Noll, 1997). Refinement of fluid and crystallized abilities corresponds with a developmental trend of improved affect recognition from childhood (Székely et al., 2011), through adolescence (Gao & Maurer, 2009) (Gao & Maurer, 2009), and into adulthood (Horning, Cornwell, & Davis, 2012). Thus, variations in the acquisition of fluid and crystallized abilities may have a differential impact on one's ability to recognize affect in others. Deficits in intellectual functioning are noted for maltreated children (De Bellis et al., 2009), which can extend throughout the life course (Noll et al., 2010) and potentially limit one's ability to recognize affect across developmental stages. Coherently, recent evidence demonstrated that maltreated females with lower levels of intellectual functioning were least accurate (i.e., total accuracy in Dynamic Affect Recognition Evaluation task) in identifying facial affect displays, whereas those with higher levels of intellectual functioning performed as well as non-maltreated females (Shenk, Putnam, & Noll, 2013). Our results, confirm these previous findings, and furthermore demonstrate that the bias for the recognition of angry facial expression, which followed the exposure to high level of maltreatment and neglect, is not influenced by victims' cognitive performance. This conclusion strengthens the thesis according to which the bias for the recognition of angry facial expressions is a manifestation of the functional adaptation of low level mechanisms likely associated with perception and attention (Pollak, 2008)

In a different manner, participants' naming skill, regardless of group membership, directly predict the erroneous use of sadness label during the recognition of angry facial expressions only. Being sadness the less used label, it could be possible that higher naming skills facilitate its use in uncertain conditions in which the over-recognition of anger is not possible. The between-groups difference in naming skills might be attributed to disparity in the quality of education of the two groups. It has been demonstrated that BNT performance is significantly related to years of schooling in different samples (Barker-Collo, 2001; Manly et al., 1999; Zec, Burkett, Markwell, & Larsen, 2007). The regression analyses performed on BNT scores obtained by the two groups of participants, demonstrated that only controls' BNT score was predicted by the educational level. On the other hand, street-children's BNT score was predicted by age. Although the two groups had the same years of schooling, controls attended school regularly and were occupied in study even outside the school, whereas street-children were unable to engage themselves regularly in school. Moreover, controls attended a fee-paying school not available to street-children whom frequented a free school managed by volunteer teachers. In this context, it is not surprising that only controls' years of schooling predicted their naming skills.

Limits

The lack of validated and applicable scales on an underage African sample prevented us to formally assess and to evaluate the possible influence of psychological qualities (e.g., empathy, self-esteem, attachment style) and of potential psychiatric sequelae generally following trauma exposure (i.e., PTSD and depression).

Moreover, although it has been demonstrated that victims' age influences outcomes severity after the exposure to prolonged traumatic experiences (Schwarzwald, Weisenberg, Solomon, & Waysman, 1994; Segovia, Moore, Linnville, Hoyt, & Hain, 2012; Solomon & Dekel, 2005), as well as, general performance in emotion recognition tasks (Herba & Phillips, 2004) in the present study age neither predicted street-children's bias for the recognition of angry facial expressions nor their accuracy rate. This could be caused by a too narrow sample age-range or by inaccurate demographic information about street-children age.

Conclusion

The present study extends previous evidence demonstrating, the presence of a bias in the recognition of angry facial expressions among children currently exposed to high levels of maltreatment and neglect. The presence of a similar tendency, although significantly less pronounced, among controls suggests that early exposure to maltreatment worsens children's bias towards the identification of specific negative facial expressions. This phenomenon appears to be independent from victims' general cognitive and educational levels and from their naming skills demonstrating how the presence of trauma interferes with the perceptive and attentive mechanisms involved in the recognition of facial expressions of emotions.

Results here reported pinpoint at least two possible further line of research. On the one hand, additional researches should explore whether, beside the explicit recognition of facial expressions of emotions, children's exposure to high levels of maltreatment and neglect could also altered Facial Mimicry and RSA response to facial expressions of emotions similarly to what happens with maltreated and neglected adolescents. On the other hand, longitudinal researches, comparing people of different age, should confirm the possible absence of additive effects of trauma exposure on explicit recognition bias, here only hypothesized.

IV.a Introduction

The high levels of maltreatment and neglect in which street-children live could be described as pervasive and repetitive forms of traumatic experiences. According to international reports, street-children are generally early abandoned by their parents and rarely reintroduced in families or included in institutional care organizations. Hence, for protracted time street-children experience high level of maltreatment (e.g., intimidation, robberies, and sexual or physical assaults in the street) and live in extreme neglect conditions (e.g., limited access to basic resources, total absence of adult-care) (Aptekar, 1994).

Thanks to clinical observations and researches, it has been demonstrated that the exposure to traumatic experiences during childhood, and particularly to protracted hostile conditions, causes brief- and long-terms alterations of victims' sense of self, emotion regulation, impulse control, social functioning and social relationships (see Chapter II - paragraph II.a for an extensive description) (Cloitre et al., 2009, 2011). Prolonged maltreatment and neglect suffered during childhood seem to represent a substantial threat to children's social development and peer relationships as confirmed by researches indicating a strong association between physical abuse and externalizing problems such as aggression and conduct disorders (Jaffee, Caspi, Moffitt, & Taylor, 2004). Furthermore, abused children tend to show low rates of prosocial behaviors, including failure to help peers and comfort others in distress (Klimes-Dougan & Kistner, 1990).

These clinical observations are supported by recent evidence obtained among street-boys and previously described (see Chapter II). In summary, street-boys, with respect to age-matched controls, evidenced reduced EMG responses during the observation of both positive and negative expressions. Moreover, they showed lower RSA after observation of facial expressions of emotions and an ineffective RSA suppression during presentation of non-threatening facial expressions of emotions (i.e., fear, joy and sadness facial expressions). These findings suggest that childhood exposure to both maltreatment and neglect influenced the physiological mechanisms related with empathic understanding of others' emotions and self-regulation in social contexts (Ardizzi et al., 2013).

Furthermore, carrying out a forced choice facial expressions recognition task on adolescents and children exposed to similar high levels of maltreatment and neglect in two different experiments (see Chapters II and III), similar biases in the recognition of angry facial expressions have been evidenced. This similar pattern of results suggested that, regardless of the degree of trauma exposure, an explicit bias in the recognition of angry facial expressions could be identified. Until today, no study investigated whether also the alteration in Facial Mimicry and vagal regulation responses to facial expressions of emotions observed among street-boys could also be present in a sample of children exposed to maltreatment and neglect.

Despite the lack of specific investigations regarding Facial Mimicry and vagal regulation in response to facial expressions of emotion some recent researches addressed similar related topics. Neuroimaging studies conducted on children exposed to protracted conditions of maltreatment and neglect demonstrated a significantly reduced anatomical volume of brain regions involved in self-regulation and emotion understanding (e.g., amygdala, orbitofrontal cortex, hippocampus) (Hanson et al., 2010, 2014, 2011). Only one empirical study investigated maltreated children's Facial Mimicry to others' emotions (Shackman & Pollak, 2014). In that study, physically maltreated children exhibited greater Corrugator EMG activity and more aggressive behavior, compared to non-maltreated children, when involved in a peer-directed aggression task. The relation between Corrugator EMG activity and aggressive behaviors was mediated by children's allocation of attention to angry faces, measured by P3b ERP component. This greater Corrugator activity was interpreted as an index of higher negative affect to others' anger expressions (Shackman & Pollak, 2014). Greater attention has to be paid on altered self-regulation after prolonged trauma exposure by the investigation of children's autonomic regulation. During social interactions with significant adult figures, abused and maltreated children showed lower RSA responses than controls (Oosterman et al., 2010; Skowron et al., 2014), an index of reduced social engagement (S W Porges, 2003a), suggesting the recruitment of defensive sympathetic behavioral strategies (e.g., fight/flight). In agreement with this last hypothesis, elevated levels of cortisol were detected in post-institutionalized children during interpersonal contact with caregivers (Fries et al., 2008). In some cases, an additive effect of trauma exposure was also found. For example, Hanson et al., (2014) evidenced smaller amygdala and hippocampal volumes associated with greater cumulative stress exposure and behavioral problems. Similarly, even if in a non-linear fashion, impact of exposure has been found to affect amygdala volume reduction (Hanson et al., 2014). In similar vain, a study analyzing autonomic reactivity to an adapted Trier Social Stress Test among non-, early-, and postinstitutionalized children revealed that early adopted children displayed a blunted cortisol response to a laboratory stressor but not post-institutionalized or non-adopted children (Gunnar, Frenn, Wewerka, & Ryzin, 2009). These authors proposed that moderate levels of early life stress as opposed to severe levels might be associated with a blunted cortisol response (Gunnar et al., 2009).

Taken togheter these results demonstrate an alteration of the neurophysiological substrates of empathic understanding of others' emotions and self-regulation also among children exposed to maltreatment and neglect. Moreover, they suggest the presence of linear and non-linear influences of trauma exposure to the neurophysiological and autonomic mechanisms being investigated.

From this point of view, it appears particularly interesting to replicate previous research conducted on street-boys, recruiting younger participants exposed to similar hostile conditions. The aim of the present study was to investigate, for the first time, Facial Mimicry and vagal regulation to positive and negative emotion facial expressions among street-children exposed to high level of repetitive maltreatment and neglect. Street-children lived in the same condition of street-boys, but thanks to their younger age were less exposed to prolonged maltreatment and neglect. For this reason, and accordingly with previous studies, we expected to find similar, but less severe, modulation of Facial Mimicry and vagal regulation with respect to what found among street-boys.

IV.b Method

Participants

Sixty Sierra Leonean children were recruited for the study, 30 were street-children collected directly in the street or in school enrolling abandoned children and 30 were control children engaged in private schools. All children filled an anamnestic questionnaire through which their demographic information (i.e., sex, age, schooling, main language, ethnicity), actual and past life and health conditions (i.e., housing detail, necessities goods, history of tropical and infective pathologies, medical treatment), their socio-economic status (i.e., individual or family members' income, occupation and education) and critical life events (i.e., sexual violence, physical violence, abuse, neglect, maltreatment, mourning) were obtained. Partial or unclear information was completed and checked thanks to sanitary, educational or charitable institutions. In order to control for between group differences in participants' cognitive performance and naming skills, Colored Progressive Matrices (CPM) (Raven, 1995) and Boston Naming Test (BNT) (Kaplan et al., 1983) were administered. Participants who suffered from cardio-respiratory or psychiatric diseases and those who used drugs interfering with the cardio-respiratory activity were excluded from the sampling. Moreover, children resulting outlier (2 SD) for each dependent measure and those who had more than 30% of trials rejected for artifacts were also excluded. The resulted final sample counted 44 participants. Of these 24 were street-children [Street-Children group (STch); mean age 7.71 years SE 0.32; mean years of schooling 2.50 SE 0.27; 12 males] and 20 were controls [Control (Con) group; mean age 7.35 years SE 0.38; mean 2 years of schooling SE 0.23; 9 males]. All children belonging to STch group were homeless, they lived without a responsible adult and the street was their only source of basic needs (e.g., food, water, clothes, shelter). Control children had never been street-children, they lived with their parents or close relatives and they regularly attended to school. No significant differences were found between STch and Con groups either for age ($t_{39.34} = 0.72$; $p = 0.47$), years of schooling ($t_{41.83} = 1.41$; $p = 0.16$), CPM score ($t_{41.66} = 0.01$; $p = 0.99$) and BNT score ($t_{42} = -0.95$; $p = 0.35$). See Table 1 for participants' demographic information and questionnaires scores. Among street-children, 62.5% experienced physical violence and 12.5% fell victim of sexual violence, of these 8.3% had suffered both physical and sexual violence. Otherwise, 10% of children belonging to Con group were exposed to physical violence and nobody experienced sexual violence. All participants were literate; Temne (33.33%), Limba (28.57%) and Mende (16.67%) were the most frequent main languages spoken.

	n.	Males	Age (years)	Schooling (years)	BNT score	CPM score	Physical Abuse (%)	Sexual Abuse (%)
STch	24	12	7.71 (0.32)	2.50 (0.27)	11.33 (0.98)	18.67 (0.83)	62.5	12.5
Con	20	9	7.35 (0.38)	2 (0.23)	12.60 (0.90)	18.65 (0.82)	10	-

Table 1: Participants' demographic information and questionnaires scores. Standard errors are given in parenthesis. STch: Street-Children group; Con: Control group; BNT: Boston Naming Test; CPM: Colored Progressive Matrices.

Procedure

The experimental procedure consisted of the same perceptive task already employed on adolescent sample (Ardizzi et al., 2013) and previously extensively descripted in Chapter II (see Chapter II – paragraph II.b, Procedure sub-session). To avoid confounding effects, participants were all recorded in the morning two hours after food intake. Children sat comfortably at a table in front of a monitor (1024X768@75Hz), they were asked to carefully observe the video stimuli.

Stimuli were the same 64 video-morphing adopted in Ardizzi et al., (2013) constructed by using the Montreal Facial Displays of Emotion stimulus set . The video-morphing, lasting 3000 msec (15 fps; 8006560 pixels), showed the transition from a neutral facial expression to an emotional one (16 anger, 16 fear, 16 joy and 16 sadness). Each emotion expression was modeled by Asian, African, Hispanic and Caucasian actors balanced for gender (4 stimuli for each ethnic group, 2 males and 2 females). Stimuli were presented using EPrime 2.0 software (Psychology Software Tools, Inc.).

The experiment consisted of four ‘‘condition-blocks’’ (each lasting 192 sec) and two ‘‘baseline blocks’’ (each lasting 120 sec). The four ‘‘condition-blocks’’, one for each emotional condition (anger, fear, joy and sadness), were randomly presented. Inside each ‘‘condition-block’’ the sixteen stimuli, comprising the same emotion, were randomly presented three times (48 trials). Each stimulus was preceded by a fixation cross lasting one second. The two ‘‘baseline-blocks’’, consisting of a black centered fixation cross on gray background, were performed one before (Baseline) and one after (Recovery) the four ‘‘condition-blocks’’. Overall the physiological experiment lasted 17 min. In order to maintain participants' attention, after each ‘‘condition-block’’ the experimenter posed a question about the videos just shown. Participants’ faces were video-recorded to ensure that they looked at the screen.

Facial electromyography (Facial EMG) and Respiratory Sinus Arrhythmia (RSA) were recorded and subsequently extracted, following the same procedure adopted by Ardizzi et al., (2013). Data were converted and amplified with an eight-channel amplifier (PowerLab8/30; ADInstruments UK) and displayed, stored, and reduced with LabChart 7.3.1 software package (ADInstruments, 2011).

Facial EMG: 4 mm Ag/Ag-Cl electrodes were bipolarly attached on the left side of the face over Corrugator Supercilii and Zygomaticus Major muscle regions (Fridlund & Cacioppo, 1986). Participants’ skin was cleaned and prepared by alcohol solution and the electrodes were filled with gel conductive paste. Facial EMG were sampled at 2 kHz and recorded with an online Mains Filter (adaptive 50 Hz filter). A 20–500 Hz band-pass filter (van Boxtel, 2001) was applied offline on the raw facial EMG signal. Following standard practice, the average amplitude of the EMG signal was obtained via root-mean-square method and EMG response (expressed in microvolts, μV) was computed as change scores between activity during each 500 msec of the 3 sec stimulus period and the 500 msec of the fixation cross immediately preceding stimulus onset. (Fridlund & Cacioppo, 1986). EMG signals were screened for artifacts by a blind coder who firstly deleted trials with artifacts due to electrical noise (less than 3.5% of removed trials), and subsequently, who inspected participants' faces video to remove trials affected by motion artifacts (i.e., a variety of facial movements not directly related to stimuli observation but affecting the EMG signal like cough, sneeze, yawn). The total average percentage of removed trials was 18.68% ± 6.10.

RSA: Three 10 mm Ag/AgCl pre-gelled electrodes (ADInstruments, UK) were placed in an Einthoven's triangle configuration. The ECG was sampled at 1 kHz and online filtered with the Mains Filter. The peak of the R-wave of the ECG was detected from each sequential heartbeat. The R-R intervals were extracted and the artifacts edited by integer division or summation (Berntson et al., 1997). Editing consisted of visual detection of outlier points, typically caused by failure to detect an R-peak (e.g., edit via division) or faulty detections of two or more ‘‘peaks’’ within a period representing the R-R interval (e.g., edit via summation). The amplitude of RSA was quantified with CMetX (available from http://apsychoserver.psych.arizona.edu) that produces data with a correlation near the unity with those obtained using Boher & Porges method (Allen et al., 2007). The amplitude of RSA [expressed in ln(msec)2] was calculated as the variance of heart rate activity across the band of frequencies associated with spontaneous respiration (0.12–0.40 Hz). RSA was extracted for the entire duration of each “condition-block” and each “baseline-block”, according to guidelines (Berntson et al., 1997). To assure an homogeneous computation of RSA amplitude this procedure was conducted on consecutive epochs lasting 30 sec both for Baseline, Recovery and for each condition-block. Hence, the Baseline and Recovery RSA values resulted from the average of 4 consecutive epochs, whereas the condition-blocks RSA values was obtained by the mean of 6 consecutive epochs. The RSA suppression value for each condition-block was measured as a change of scores between the RSA of the condition-block and Baseline RSA value.

Statistical Data Analyses

To verify between groups differences in facial EMG activations during the visualization of facial expressions of emotions, two separate repeated-measures ANOVAs, one for each recorded muscle (Corrugator Supercilii and Zygomaticus Major), were conducted with Group (STch, Con) and Sex (M, F) as between-factors and with Emotion (anger, fear, joy, sadness) and Epoch (6 epochs, each lasting 500msec) as within factors.

Accordingly to guidelines (Girden, 1992), when the sphericity assumption was violated, Geisser–Greenhouse correction was calculated and adjusted df, corrected p values, and epsilon values (Ɛ) reported. Whenever appropriate, significant between and within groups differences were explored performing Tukey post-hoc comparison. Partial eta square (η^2_p) was calculated as effect size measure.

Two independent sample t-tests (two-tailed), one for Baseline RSA values and one for Recovery RSA values were performed comparing the two experimental groups to investigate possible differences between groups in RSA values recorded before and after experiment execution. Since, no significant differences between groups were found, a dependent sample t-test (two tailed) was conducted contrasting Baseline and Recovery RSA values of all participants, regardless of group membership, to investigate possible experiment influence on RSA values. Bonferroni correction for multiple comparisons was applied on p_s significant levels.

Finally, in order to verify the existence of a significant correlation between Mean Baseline RSA and the levels of RSA suppression measured during the presentation of threatening stimuli, two Pearson's Correlations analyses (one for each group) were performed on Mean Baseline value and the RSA suppression values of each condition (M A Patriquin et al., 2011).

IV.c Results

Facial EMG

Corrugator Supercilii – Repeated-measures ANOVA conducted on Corrugator EMG activity revealed a significant main effect of the factor Emotion ($F_{3,120} = 5.12$, $p = 0.002$; $\eta^2_p = 0.11$) and a significant interaction Emotion by Group ($F_{3,120} = 3.46$, $p = 0.02$; $\eta^2_p = 0.08$).

Post-hoc comparisons conducted on the main effect of Emotion revealed that corrugator EMG activity recorded in response to joy facial expressions (-0.09 µV, SE 0.16) was significantly lower than corrugator EMG activity measured in response to both angry (0.63 µV, SE 0.20; p = 0.03), and fear facial expressions (0.75 µV, SE 0.25; p = 0.01). No significant difference was found between joy and sadness corrugator EMG activity (0.48 µV, SE 0.12; p = 0.14). This last result was explained considering Emotion by Group Interaction (Figure 17). Post-hoc comparisons performed on Emotion by Group interaction showed that only among controls the Corrugator EMG activity in response to joy facial expression resulted significantly lower than that recorded in response to all other negative facial expressions (all $p_s < 0.05$). No significant differences were found among street-children in Corrugator EMG activity during positive and negative facial expressions visualization (all $p_s > 0.05$). Moreover, post-hoc analyses did not evidence significant between groups differences (all $p_s > 0.05$).

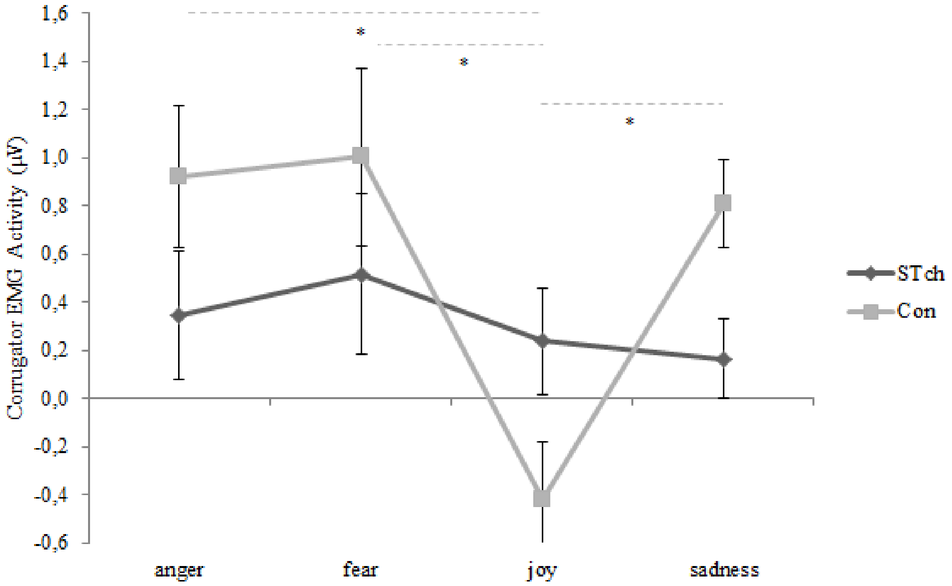

Figure 17: Corrugator EMG Activity for Street-Children group (STch) and Control group (Con) during presentation of emotional facial expressions. * = p < 0.05. Error bars represent SE.

Zygomaticus Major - Mauchly's test conducted on Zygomaticus EMG activity showed a violation of sphericity assumption for Emotion ($\chi^2_{(5)} = 153.27$, $p < 0.001$) and Epoch factors ($\chi^2_{(14)} = 326.51$, $p < 0.001$), as well as for Emotion by Epoch interaction ($\chi^2_{(119)} = 885.70$, $p < 0.001$). Hence degrees of freedom were adjusted using Greenhouse-Geisser correction (Emotion: $\varepsilon = 0.37$; Epoch: $\varepsilon = 0.23$; Emotion by Epoch: $\varepsilon = 0.09$). Repeated measures ANOVA conducted on Zygomaticus EMG activity revealed a significant effect of the factor Emotion ($F_{1.12,44.98} = 5.79$, $p = 0.017$; $\eta^2_p = 0.13$). Post-hoc comparisons conducted on that main effect revealed that Zygomaticus EMG activity recorded in response to joy facial expressions (3.37 µV, SE 1.82) was significantly higher than Zygomaticus EMG activity measured in response to both anger (-1.19 µV, SE 0.27; p = 0.01), fear (-0.51 µV, SE 0.53; p = 0.03) and sadness facial expressions (-0.89 µV, SE 0.23; p = 0.01).

RSA

Baseline and Recovery RSA - Bonferroni corrected t-tests (with α 0.05 = 0.016) comparing STch and Con groups' Baseline (STch: 5.90 ln(msec)^2, SE 0.34; Con: 6.15 ln(msec)^2, SE 0.27) and Recovery (STch: 5.90 ln(msec)^2, SE 0.28; Con: 6.08 ln(msec)^2, SE 0.26) RSA values respectively, resulted not significant (Baseline: t_{42} = -0.55, p = 0.58; Recovery: t_{39} = -0.46, p = 0.65).

Considering all participants, regardless of group membership, Bonferroni corrected t-test comparing Baseline (6.01 ln(msec)^2, SE 0.22) and Recovery RSA (5.98 ln(msec)^2, SE 0.19) values resulted not significant (t_{83} = -0.11, p = 0.91).

RSA suppression – Two-tailed Pearson's correlations performed for STch group (Table 2 and Figure 18) demonstrated a significant negative relation between Baseline RSA and Suppression RSA in response to angry facial expressions (r_{24} = -0.55; p = 0.005). Moreover, RSA suppression values obtained in response to negative facial expressions (anger, fear and sadness) resulted to be significantly correlated.

Group			Baseline	Suppression Anger	Suppression Fear	Suppression Joy	Suppression Sadness
STch	Baseline	r		**-,549***	-,273	-,027	-,396
		Sig. (2-code)		,005	,198	,902	,055
		N		24	24	24	24
	Suppression Anger	r	-,549*		**,533***	,039	**,580***
		Sig. (2-code)	,005		,007	,856	,003
		N	24		24	24	24
	Suppression Fear	r	-,273	**,533***		-,095	**,624***
		Sig. (2-code)	,198	,007		,660	,001
		N	24	24		24	24
	Suppression Joy	r	-,027	,039	-,095		,025
		Sig. (2-code)	,902	,856	,660		,906
		N	24	24	24		24
	Suppression Sadness	r	-,396	**,580***	**,624***	,025	
		Sig. (2-code)	,055	,003	,001	,906	
		N	24	24	24	24	

Table 2: Pearson's correlation between Baseline RSA and Suppression RSA for Street-Children Group. R coefficients (r), p values (Sig.) and number of cases (N) were displayed. STch = Street-Children Group; * = p < 0.05

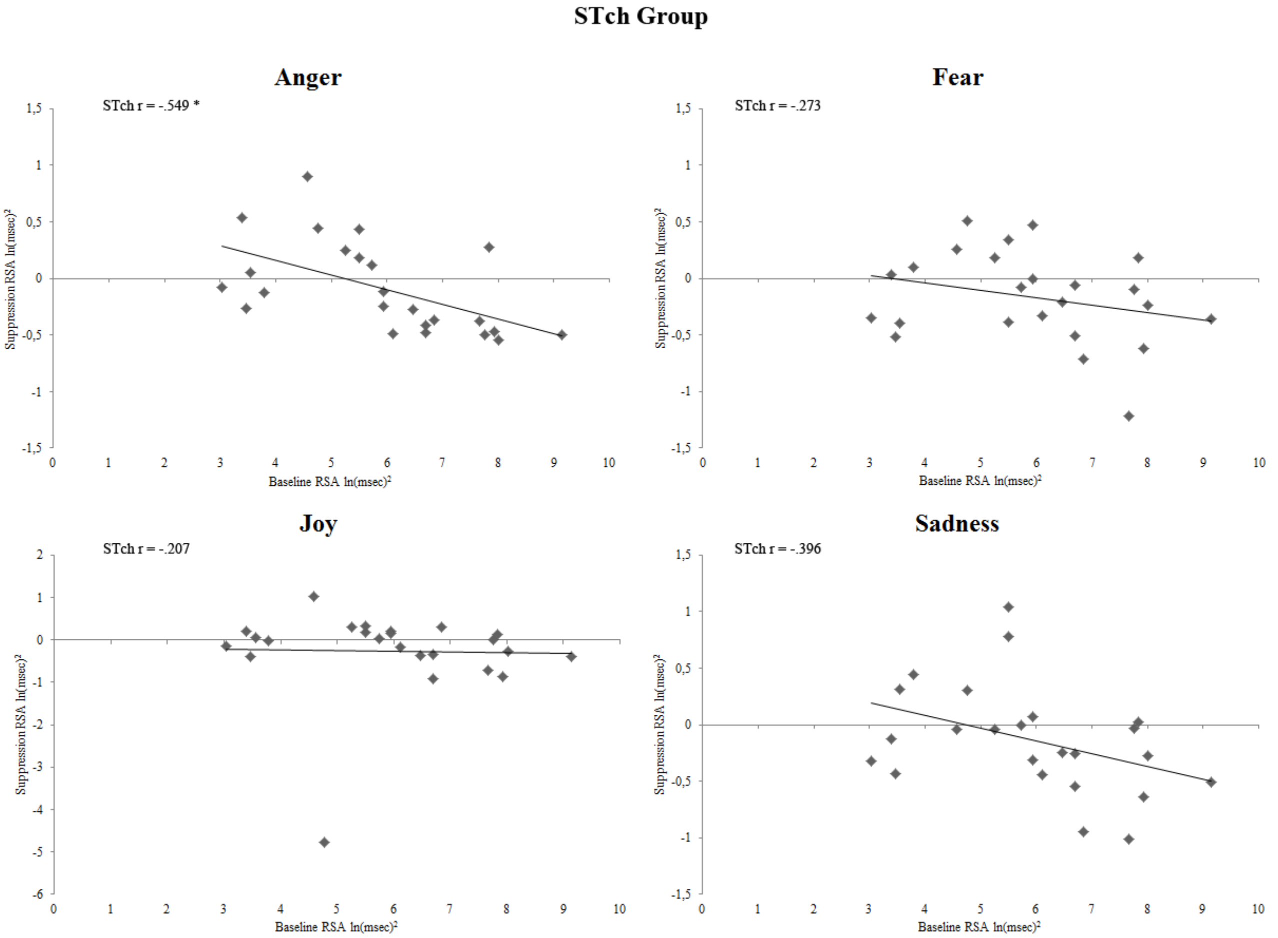

Figure 18 – Plots of correlation between Mean Baseline and Suppression RSA values for street-children Group displayed emotion by emotion. STch = street-children. * = $p<0.05$.

On the contrary, two-tailed Pearson's correlations performed on Con group (Table 3 and Figure 19) revealed an absence of significant relations between Baseline RSA and Suppression RSA in response to all facial expressions. Furthermore, the RSA suppression values in response to both positive and negative facial expressions of emotions appeared to be positively correlated.

Group			Baseline	Suppression Anger	Suppression Fear	Suppression Joy	Suppression Sadness
Con	Baseline	r		-,356	-,296	-,401	-,201
		Sig. (2-code)		,123	,204	,079	,396
		N		20	20	20	20
	Suppression Anger	r	-,356		,808*	,743*	,467*
		Sig. (2-code)	,123		,000	,000	,038
		N	20		20	20	20
	Suppression Fear	r	-,296	**,808***		**,846***	**,567***
		Sig. (2-code)	,204	,000		,000	,009
		N	20	20		20	20
	Suppression Joy	r	-,401	**,743***	**,846***		**,800***
		Sig. (2-code)	,079	,000	,000		,000
		N	20	20	20		20
	Suppression Sadness	r	-,201	**,467***	**,567***	**,800***	
		Sig. (2-code)	,396	,038	,009	,000	
		N	20	20	20	20	

Table 3: Pearson's correlation between Baseline RSA and Suppression RSA for Control Group. R coefficients (r), p values (Sig.) and number of cases (N) were displayed. Con = Control Group; * = $p < 0.05$

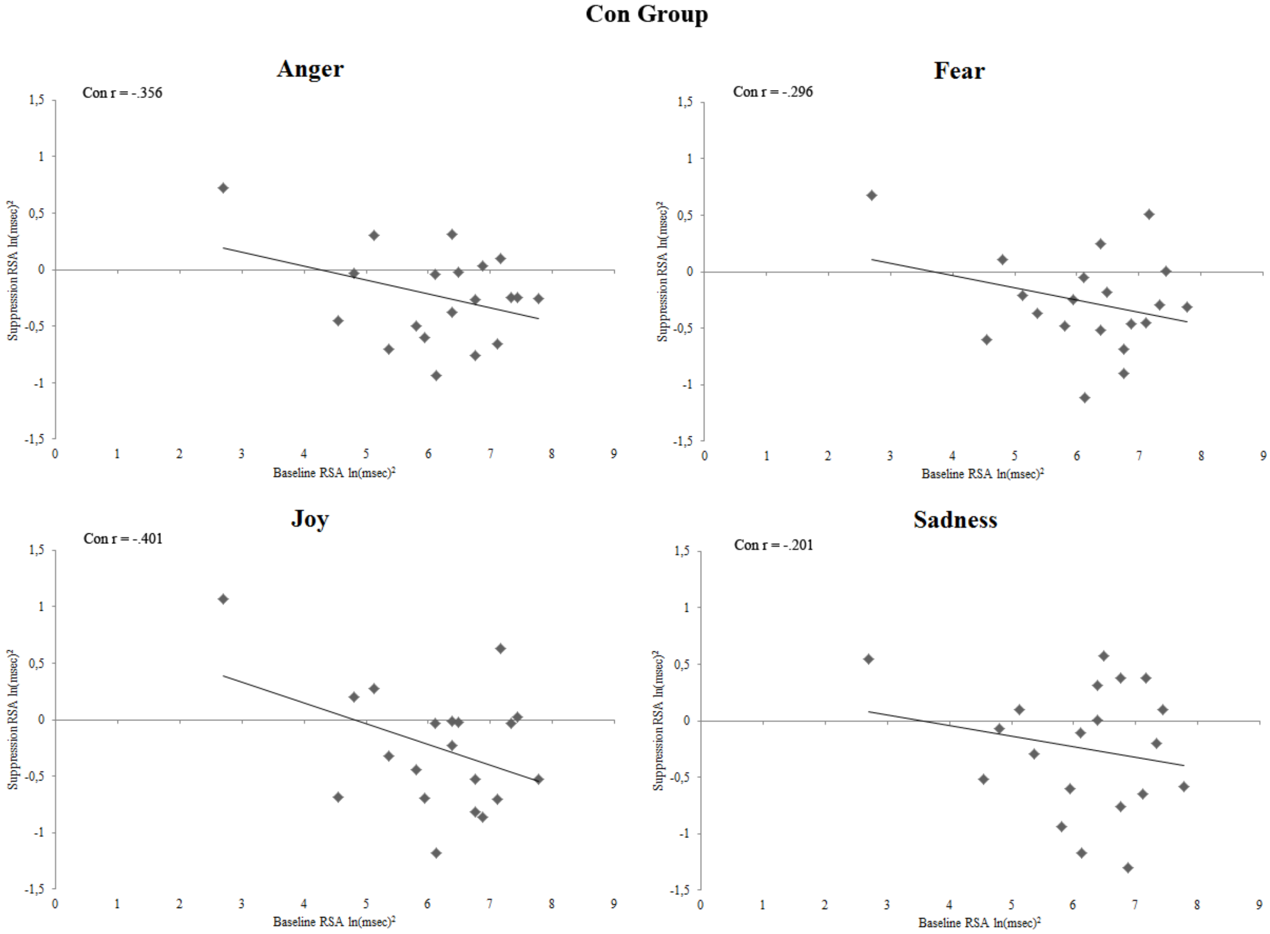

Figure 19 – Plots of correlation between Mean Baseline and Suppression RSA values for control Group displayed emotion by emotion. Con = Control. * = p<0.05.

IV.d Discussion

The aim of the present study was to investigate, for the first time, Facial Mimicry and vagal regulation to positive and negative emotional facial expressions among street-children exposed to high level of repetitive maltreatment and neglect experiences. To this aim a group of street-children, and an age-matched control group, performed a simple facial expressions of emotions perceptive task during which spontaneous facial EMG activations and RSA were recorded.

Results demonstrated that street-children early exposed to repetitive traumatic experiences showed a modulation of physiological mechanisms functionally employed in empathic understanding of others' emotion and self-regulation. Specifically, street-children did not differ from controls for the amplitude of physiological responses. Indeed, we did not find any significant differences between groups in muscles activation to positive and negative emotions, as well as, in RSA values recorded at Baseline and Recovery were not found. Rather, street-children, but not controls, showed an absence of modulation of Corrugator facial mimicry in response to positive and negative facial expressions of emotions. Moreover, street-children manifested a significant correlation between Baseline RSA and RSA suppression values in response to angry facial expression, whereas, control children did not show significant correlation between Baseline RSA and RSA suppression values recorded in response to both negative (i.e., anger, fear and sadness) and positive (i.e., joy) facial expressions of emotions. Considering RSA suppression values in response to different facial expressions of emotions, street-children showed significant correlations between RSA suppression values to negative facial expressions (i.e., angry, fear and sadness facial expressions). Differently, control children showed significant correlations between RSA suppression values to both positive and negative facial expressions of emotions.

The absence of significant differences between groups in the amplitude of muscles activations during facial expressions of emotions visualization and of RSA values recording in resting conditions demonstrated that the effect of early exposure to adverse experiences causes, at least in children population, not an overall impairment of these physiological mechanisms, but rather an alteration of the functional modulation of these physiological responses. Among adolescent sample of street-boys, previously involved in the same facial expressions of emotions perceptive paradigm (Ardizzi et al., 2013) it was evidenced an overall significantly reduced muscle activation, as well as significantly lower RSA values recorded after facial expressions of emotions exposure, when compared to age-matched controls. Being both samples (street-children and street-boys) exposed to identical conditions of maltreatment and neglect and submitted to the same experimental protocol, the different level of impairment of their physiological responses could be due to different time exposure to prolonged traumatic experiences. This consideration, at this time, remain exclusively speculative. Further longitudinal researches, directly comparting the two groups and estimating the effect of trauma exposure time, are needed to assess this intriguing point.

The lack of difference between street-children and controls in Corrugator EMG activity to negative facial expressions of emotions, appeared to be quite different from what reported by Shackman & Pollak (2014). These authors showed that maltreated children when involved in a peer-directed aggression task displayed greater Corrugator EMG activity (Shackman & Pollak, 2014). The incongruent results could be explained by differences in the used paradigms. First, in Shackman & Pollak task, EMG was recorded in response to peers' negative affect, whereas in the experimental protocol we employed stimuli depicted facial expressions of emotions displayed by adult models. This is a crucial difference, especially when considering young's EMG responses to peer facial expressions (Ardizzi et al., 2014). Second, but not less important, whereas the children studied by Shackman & Pollak children participated in a provocation task designed to elicit reactive aggression, the street-children involved in the present study performed a simple perceptive task, undoubtedly less arousing and chosen to record physiological measures.

The absence of between groups differences in muscles activation does not mean that the exposure to early traumatic experiences did not influence Facial Mimicry responses to facial expressions of emotions. Whereas control children showed the expected modulation of Corrugator activity between positive and negative facial expressions of emotions, street-children did not. Normally Corrugator muscle reaction is facilitated by negative stimuli (e.g., anger, fear and sadness facial expressions) and suppressed by positive stimuli (e.g., joy facial expressions). A reverse pattern of activation is attested for zygomatic muscle reaction to negative and positive stimuli (Dimberg, Thunberg, & Grunedal, 2002). This positive/negative distinction is completely automatic and involuntary as demonstrated by the fact that also when participants were required not to react with their facial muscles at all, they could not avoid producing a facial reaction that corresponded to the observed negative and positive stimuli (Dimberg et al., 2002). Such specific different muscular responses have been found to significantly predict experienced emotional valence in response to dynamic facial expressions. Specifically, the activity of the Corrugator and Zygomatic muscles was negatively and positively related to experienced emotional valences from negative to positive, respectively (Sato, Fujimura, Kochiyama, & Suzuki, 2013). Accordingly, in a different study employing ambiguous facial expressions, corrugator activity reflected an individual's general bias in interpreting the valence of these faces. Specifically, individuals who tended to interpret surprised faces as negative displayed higher corrugator muscle activity to all surprised faces, while those who tended to interpret surprised faces as positive displayed greater attenuation of corrugator activity to all surprised faces (Neta, Norris, & Whalen, 2010). In summary, Corrugator modulation between positive and negative facial expressions seem to be functionally linked to emotional valence attribution to others' facial expressions of emotions. Coherently, lack of difference in Corrugator responses during observation of positive and negative emotions was described also among children suffering of Autism Spectrum Disorders (McIntosh et al., 2006) who showed deficit in emotion recognition (Baron-Cohen, 2010). Similar Corrugator activation pattern was found among street-boys exposed to high level of maltreatment and neglect, as described in Chapter I. Street-boys, but not controls, demonstrated an absence of Corrugator EMG response modulation to positive and negative facial expressions of emotions (Ardizzi et al., 2013). This result, when compared with what we found here in street-children, suggests that in a younger population exposed to similar but less protracted hostile conditions, before an overall decrement in Facial Mimicry responses, the unconscious valence attribution to positive and negative facial expressions of emotion was distorted. In other words, before an alteration of the overall empathic resonance by means of a general Facial Mimicry suppression, it is the ability to implicitly differentiate between positive and negative emotional valence to be damaged first. It is important to note that Zygomaticus muscular responses were not influenced by early exposure to maltreatment and neglect. Hence, no differences were found between street-children and controls in Zygomaticus responses to positive and negative facial expressions of emotions. These data suggest that, at an implicit level, Facial Mimicry response to positive facial expressions are more resistant to external environmental influences. Joy facial expression is the best recognized emotion among both maltreated and control children (Ardizzi et al., 2013, 2014; Pollak & Sinha, 2002), moreover it is the first basic emotion to be recognized (Adolphs, 2002) and the first one to be spontaneously imitated (Wörmann, Holodynski, Kärtner, & Keller, 2012). Bearing in mind these assumptions, higher levels of trauma exposure might be necessary to alter congruent facial mimicry to joy facial expressions.

Given the observed deficient valence discrimination, caused by unmodulated Corrugator EMG activity to positive and negative facial expressions of emotions, one could have expected to find a consequently altered vagal regulation in response to positive and negative facial expressions of emotions. Surprisingly, it did not occur. Street-children showed a coherent significant correlation between Baseline RSA value and RSA suppression during the observation of angry facial expressions, but not when positive (i.e., joy) and non-threatening negative (i.e., fear and sadness) facial expressions were presented. Higher baseline and greater RSA suppression are considered indexes of better ability to engage and disengage with the environmental requests (Julian F Thayer, 2012). Accordingly, individuals with higher baseline RSA should show greater RSA suppression to meet metabolic demands of taxing environmental conditions, including threatening stimuli. The vagal suppression to aversive facial expressions represent an adaptive and coherent autonomic modulation to external environmental stimuli which allows a functional recruitment of defensive behavioral strategies (e.g., fight/flight or immobilization). Hence, a significant negative correlation between Baseline RSA value and Suppression RSA values during the observation of angry facial expression should be expected. No significant correlation was anticipated in response to joy, fear and sadness facial expressions, being the first one a socially engaging expression and the other two being negative but not directly aversive expressions of emotion. Coherently, in the control adolescent population a significant vagal suppression was only found during the observation of angry facial expressions (Ardizzi et al., 2013). It is possible that the exposure to negative and aggressive environments might induce an earlier development of the functional synchronization between vagal regulation and the external environment, which, in normal conditions are established in subsequent developmental stage. This interpretation can be supported by two observations. First, controls did not show any significant correlation between Baseline RSA value and RSA suppression values in response to all facial expressions employed in the study, suggesting a still underdeveloped functional synchronization between vagal regulation and the external environment. Secondly, whereas RSA suppression values of street-children group recorded in response to *all negative expressions* were significantly correlated with each other, among controls significant positive correlations were found between RSA suppression values in response to *all facial expressions*. These results suggest that while the vagal regulation observed among street-children is functionally influenced by stimuli affective valence, the vagal regulation manifested by controls did not. These observations suggest the presence of a still immature vagal regulation to social stimuli among controls but not among street-children, whose living conditions required an earlier functional adaptation of autonomic regulation to a challenging social context.

Limits

The lack of validated and applicable scales on an underage African sample prevented us to formally assess and to evaluate the possible influence of psychological qualities (e.g., empathy, self-esteem, attachment style) and of potential psychiatric sequelae generally following trauma exposure (i.e., PTSD and depression).

In the present study the explicit valence judgments of facial expressions of emotions were not recorded. Hence, it prevents the authors to directly confirmed the impact of the absent Corrugator modulation to those judgments.

Finally, in the present study there was no direct comparison between street-children and street-boys groups. Consequently, suggestions regarding additive trauma exposure effect have to be confirmed by further studies specifically addressing this point.

Conclusion

The present results demonstrate an early, although differentiated, influence of childhood exposure to high levels of maltreatment and neglect on Facial Mimicry and vagal regulation during the perception of facial expressions of emotions. On the one hand, early traumatic experiences induce an alteration in Corrugator EMG modulation between positive and negative facial expressions, a mechanism associated to emotional valence discrimination. On the other hand, early exposure to high level of maltreatment and neglect induce an earlier development of the functional synchronization between vagal regulation and threatening stimuli in external environment.

When comparing the physiological results obtained in older adolescent population exposed to similar averse conditions, a possible additive effect of trauma exposure could be expected. Further research directly comparing populations exposed to different degrees of prolonged traumatic experiences are needed to confirm this hypothesis.

V.a Introduction

Previous chapters (see Chapters II, III and IV) described facial expressions of emotions recognition, along with, Facial Mimicry and vagal regulation of children and adolescents exposed to repetitive and prolonged experiences of maltreatment and neglect. Results demonstrated the presence of a significant influence of childhood experiences on the investigated processes, also suggesting the occurrence of possible additive effect of trauma exposure. Indeed, when compared to age-matched controls, adolescents currently exposed to maltreatment and neglect manifested a significant suppression of Facial Mimicry responses to both positive and negative facial expressions of emotions and a significantly lower vagal regulation after facial expressions visualization. On the contrary, children exposed to the same hostile conditions did not. Furthermore, adolescents and children with current histories of maltreatment and neglect showed an opposite pattern of vagal regulation to others' facial expressions. As illustrated, street-boys manifested an incoherent significant vagal withdrawal in response to both positive and non-threatening facial expressions of emotions (i.e., fear, joy and sadness), whereas street-children manifested a predictable vagal withdrawal only in response to threatening expressions (i.e., anger). Being both samples (street-children and street-boys) exposed to identical conditions of maltreatment and neglect and submitted to the same experimental protocols, the different level of impairment of their physiological responses could be due to different time exposure to prolonged traumatic experiences. However, these previous studies did not directly compare experimental populations exposed to different levels of trauma. Hence, the demonstration of specific impact trajectories was prevented.

The existence of an additive effect of trauma exposure was suggested by several studies focusing on youth population. Most of them investigated the cumulative effect of being exposed to multiple traumatic events. This approach was established by the work of Sameroff et al., (1987) who created a cumulative risk index and found strong relations between the total accumulation of ecological risk and both cognitive (A. J. Sameroff, Seifer, Barocas, Zax, & Greenspan, 1987) and social-emotional outcomes (A. Sameroff, Seifer, Zax, & Barocas, 1987). Since those pioneering studies, more recent investigations confirmed these findings in different samples within a variety of social and cognitive domains. Regarding clinical and psychiatric consequences of trauma exposure, a positive correlation between severity of posttraumatic stress symptoms and severity of exposure to traumatic event has been evidenced. This cumulative effect among children has been found following a variety of events (Hoven et al., 2005; Pfefferbaum et al., 1999, 2000). Recently, Mullet-Hume et al., (2008) demonstrated that the long-term sequelae of direct exposure to the 9/11 WTC attack differed for children depending on their history of trauma experience. For those with low accumulation of other life traumas, a significant dose-response effect in PTSD symptom severity was obtained 2.5 years post-event. In contrast, children with medium to high levels of cumulative life traumas evidenced significantly higher levels of 9/11 PTSD symptoms, but the severity of them was best predicted by the accumulation of other life traumas rather than the dose of 9/11 exposure, which appeared essentially irrelevant (Mullett-Hume, Anshel, Guevara, & Cloitre, 2008). Coherently, multiple types of adverse childhood experiences appeared as risk factors for a spectrum of violence-related outcomes during adolescence (Duke, Pettingell, McMorris, & Borowsky, 2010). As expected, a link between the number of different types of maltreatment experiences and victims' psychopathology ratings was established also in brief-term examinations (Boxer & Terranova, 2008). Among others, in a study investigated 296 Tamil school children in Sri Lanka's North-Eastern provinces exposed to traumatic stress related to war, family violence and the recent Tsunami experience. Results demonstrated a clear dose-effect relationship between exposure to various stressful experiences and PTSD (Catani, Jacob, Schauer, Kohila, & Neuner, 2008). The observed relation between cumulative risk and mental health symptomatology appeared to be linear: incremental increase in cumulative risk was accompanied by a proportional increase in mental health problems (Raviv, Taussig, Culhane, & Garrido, 2010). From a neuroscientific point of view an additive effect of trauma exposure has been evidenced in neuroanatomical changes following childhood trauma. Hanson et al., (2014) evidenced smaller amygdala and hippocampal volumes associated with greater cumulative stress exposure and behavioral problems. In that case, however, the exposure impact for amygdala volume reduction was non-linear (Hanson et al., 2014). Moreover, EEG abnormalities seen in trauma survivors are associated with increased frequency of violence (Heide & Solomon, 2006).

The studies briefly reviewed here focused on cumulative effect of multiple trauma experiences. In the case of protracted trauma (e.g., long-lasting conditions of maltreatment, neglect, physical abuse) the exposure to multiple and repetitive forms of traumatic events is a crucial factor but it is not the only one. As expected, the long-lasting duration of hostile conditions represents the core factor, which can lead to different subsequent adaptations. Indeed, facing on protracted negative experiences an habituation or an increasingly alteration could be expected. Unfortunaltely, little attention has been paid to the specific effect of protracted traumatic conditions on impact trajectories and their psychological and physiological consequences. Despite this, it appeared evident that protracted forms of trauma in childhood lead to psychiatric outcomes that are more severe and qualitatively different than those following a single incident trauma (Cloitre et al., 2009, 2011; Ginzburg & Solomon, 2011). Latent Profile Analysis conducted to determine whether people exposed to protracted trauma (e.g., childhood abuse) or to single-incident events (e.g., exposure to 9/11 attacks) are distinguishable on the basis of their symptom profiles, demonstrated that only chronic trauma was strongly predictive of Complex PTSD, which beside classical PTSD symptoms (i.e., Re-experiencing, Avoidance, Sense of threat) also includes disturbances in affective dysregulation, negative self-concept, and interpersonal problems (Cloitre et al., 2013). In a similar vein, a longitudinal study of the changes in psychological responses to continuous terrorism conducted on a population of 153 Jewish Israeli adults demonstrated that the prevalence of probable PTSD, the mean number of symptoms, and the rate of severe posttraumatic symptomatology (PTSS) all increased between the study waves (Gelkopf, Solomon, & Bleich, 2013). These findings differ from those of longitudinal studies on the impact of a single terrorist attack, which consistently show a reduction in symptomatology over time (Galea et al., 2003; Silver, Holman, McIntosh, Poulin, & Gil-Rivas, 2002). Being subjected to protracted hostile conditions induces a progressive decrement of the recognition of facial expressions of emotions. Indeed, Sloutsky (1997) investigating emotion understanding in 6- and 7-year-old children currently residing in a Russian orphanage, demonstrated that their performance to an emotion identification task was negatively related to time spent in the orphanage (Sloutsky, 1997). Differently an habituation trajectory was demonstrated for autonomic regulation following prolonged trauma. With chronic stress, the HPA-axis is down regulated and cortisol levels return to normal (Panzer, 2008). It is thought that down regulation occurs in response to a persistent chaotic environment; to prevent chronic arousal with associated excessive energy expenditure. This HPA-axis down regulation occurs in children who have suffered long-term abuse (Teicher et al., 2003). Inversely, a study analyzing autonomic reactivity to an adapted Trier Social Stress Test among non-, early-, and postinstitutionalized children revealed that early adopted children displayed a blunted cortisol response to a laboratory stressor but not post-institutionalized or non-adopted children (Gunnar et al., 2009). The authors proposed that moderate levels of early life stress as opposed to severe levels might be associated with a blunted cortisol response (Gunnar et al., 2009). These mixed results could be explained considering differences in experimental conditions involving participants. As extensively described in Chapter II, prolonged conditions of maltreatment and neglect induce significant changes not only in the overall brain activity and anatomy, but especially in cerebral regions implicated in self-regulation and emotion understanding (Hanson et al., 2010, 2013, 2014, 2011; Peter J Marshall & Fox, 2004; Sheridan, Fox, Zeanah, McLaughlin, et al., 2012). Although, as mentioned above, the investigations which focused on the effect of protracted trauma exposure are scarce, De Bellis et al., (2005) demonstrated that, not only the abuse onset, but also its longer duration correlated with smaller intracranial volume among maltreated and neglected children (De Bellis, 2005).

Bearing in mind these studies, it appears evident that the prolonged nature of traumatic experiences induces, in the victims, different adaptive responses that could change over time. Adaptive responses, tough, are not yet thoroughly understood. Particularly, to our knowledge, no study investigated the impact trajectories of prolonged maltreatment and neglect on angry facial expression recognition bias, Facial Mimicry and vagal regulation; all these fields appeared to be altered following prolonged maltreatment and neglect. The study of impact trajectories of prolonged traumatic experiences is important to gain a better picture of the natural patterns of resistance, improvement, deterioration, and chronicity.

For all these considerations, the aim of the present study was to evaluate the impact trajectories of prolonged experience of maltreatment and neglect on the recognition of facial expressions of emotion, Facial Mimicry and vagal regulation. To this aim two groups of Sierra Leonean minors (age range: 5-17 years), one composed by street-boys and one consisting of family-reared age-matched controls, performed a forced-choice facial expressions recognition task, as well as, a facial expressions perceptual task during which facial EMG activations and RSA responses were recorded. In order to evaluate the impact trajectories of prolonged condition of maltreatment and neglect, participants age was considered an indirect, but efficient, index of trauma exposure time. Considering previous studies, three different impact trajectories could be hypothesized: I) linear; II) logarithmic and III) quadratic. The first trajectory describes a proportional additive effect of trauma exposure; the second trajectory defines an habituation or a charging effect of prolonged trauma exposure. Finally the third outlines a trend inversion during exposure time.

Copious evidence attests a significant impact of childhood maltreatment and neglect on victims' emotion recognition processes (Ardizzi et al., 2013; Fries & Pollak, 2004; Masten et al., 2008; Moulson et al., 2014; Pollak et al., 2000, 2009; Pollak & Kistler, 2002; Pollak & Sinha, 2002; Scrimin et al., 2009). Thus, we expected to find a significant lower Accuracy rate among street-boys than controls in the facial expressions recognition task. A well-known consequence of early exposure to maltreatment and neglect is a sudden redirection of attentive and perceptive mechanisms to threatening environmental stimuli (Pollak et al., 2001; Pollak & Tolley-Schell, 2003; Pollak, 2008). This induces a bias in angry facial expressions recognition (Ardizzi et al., 2013; Fries & Pollak, 2004; Pollak et al., 2000, 2009; Pollak & Kistler, 2002; Pollak & Sinha, 2002; Scrimin et al., 2009). Bearing in mind these results, significantly higher Anger False Alarms Rate was expected among street-boys than in controls. Considering the influence of trauma exposure on the recognition of facial expressions of emotions, measured by participants' age, different trajectories were expected in the two groups. Behavioral studies demonstrated that, in normal conditions, the recognition of facial expressions starts early in infancy and improves through childhood, adolescence, and adulthood (Herba & Phillips, 2004). Thus, a significant positive linear relation between Age and Accuracy rate should be present in the control group. On the contrary, a significant negative linear relation or an absence of relation between Age and street-boys' Accuracy rate was expected. Previous studies demonstrated the existence of angry facial expressions recognition bias among children (see Chapter III) and adolescent (see Chapter II) exposed to prolonged condition of maltreatment and neglect. Moreover, even just the experience of a single traumatic event induces in the victim a bias for angry facial expressions recognition (Scrimin et al., 2009). These results seem to suggest the independence of this effect from trauma exposure time, allowing for the expectation of no significant relation between participants' Age and Anger False Alarms rate.

Switching to the expected results of the physiological measures recorded in the present study, a significantly lower EMG activity of the Corrugator muscle in street-boys than controls was expected. On the contrary, no significant differences were expected for Zygomaticus EMG activity, Baseline RSA and Recovery RSA values. Indeed, whereas a significant impairment in Corrugator EMG activity was already found among street-children (see Chapter IV) and street-boys (see Chapter II), no significant differences were reported for Zygomaticus EMG activity. Mixed results were reported for RSA recorded at resting conditions in the previous studies. Among adolescent samples, significantly lower RSA was recorded after experiment execution but not before experiment comparing age-matched controls. Furthermore, adolescent females exposed to childhood maltreatment showed reduced vagal activity at baseline when compared to non-maltreated coetaneous (Miskovic et al., 2009). Differently, no significant differences were found for street-children RSA values recorded both before and after experiment execution. Seeing these previous results and considering the wide age-range of our sample (4-17 years) including both children and adolescent participants, a significant difference between street-boys and controls in RSA values at resting conditions was not expected.

Regarding the influence of trauma exposure, measured by participants' age, on Corrugator and Zygomaticus EMG activities different trajectories were expected in the two groups. Despite longitudinal studies regarding typical Facial Mimicry development across different ages are still lacking, studies about Facial Mimicry in different age samples, suggest that specific muscle activations to positive and negative facial expressions are present among both children and adolescent (Ardizzi et al., 2014; Beall, Moody, Mcintosh, Hepburn, & Reed, 2008; De Wied et al., 2009; de Wied, van Boxtel, Zaalberg, Goudena, & Matthys, 2006; Dimberg & Thunberg, 1998; Oberman, Winkielman, & Ramachandran, 2009). Hence, longitudinal influence of Age in controls' Corrugator and Zygomaticus EMG activities was not expected. On the contrary, considering the altered corrugator EMG activity previously reported among both street-children and street-boys, we expected to find a significant negative linear relation between trauma exposure (measured by Age) and Corrugator EMG activity in response to the observation of negative facial expressions of emotions. No significant relations were expected for Zygomaticus EMG activities.

Longitudinal studies demonstrated that RSA exhibits significant mean level increases over time (i.e.,discontinuous) and is relatively stable through infancy and early childhood (Alkon et al., 2006; Bar-Haim, Marshall, & Fox, 2000; Bornstein & Suess, 2000; Calkins & Keane, 2004; P J Marshall & Stevenson-Hinde, 1998). RSA has been found to increase over infancy and early childhood and reach stable adult levels by 5 years of age (Bornstein & Suess, 2000; Michelle A Patriquin, Lorenzi, Scarpa, & Bell, 2014). Continuity in RSA for older children is less evident with some studies indicating mean increases in RSA with children up to 7 years of age (Alkon et al., 2006; P J Marshall & Stevenson-Hinde, 1998), while others have shown mean decreases or no change in RSA with children and adolescents (El-Sheikh, 2005; Hinnant, Elmore-Staton, & El-sheikh, 2011; Salomon, 2005). Hinnant et al., (2011) demonstrated that children's RSA exhibited significant stability over time, and that initial levels of RSA and the RSA slope over time were predicted by several demographic factors which could account for counfounding results. Specifically, RSA of European and North-American children showed significant increases over time while African-American children had higher initial RSA but no significant change over time (Hinnant et al., 2011). Taken togheter these findings suggest that, developmental change in RSA seems to level off by late childhood or early adolescence and has significant stability during these developmental periods. Hence, significant relation between Age and RSA recorded at resting conditions before and after experiment exhecution (Baseline and Recovery RSA values) was not expected among controls. On the contrary, the evidence that exposure to hostile environmental conditions influences autonomic regulation at resting condition among adolescent (Ardizzi et al., 2013; Miskovic et al., 2009) but not among children (see Chapter IV) seem to suggest a possible negative relation between Age and RSA values recording in resting condition (i.e., Baseline, Recovery) among street-boys group.

Longitudinal studies regarding normal development of vagal regulation to others' facial expressions are still lacking. However, from our previous results (see Chapters II and IV) it is possible to suppose a maturational adjustment from childhood to adolescence. Indeed, children manifested absence of vagal regulation in response to both positive and negative facial expressions of emotions (see Chapther IV), whereas, adolescents showed a coherent vagal withdrawal in response only to threatening facial expressions of emotions (see Chapther II). Considering these results a possible relation between Age and RSA response values to angry facial expressions (i.e., index of vagal withdrawal, see Chapter I for an extensive illustration) could be expected among controls. An opposite profile was evidenced among street-children and street-boys. As illustrated, street-children manifested an earlier vagal withdrawal in response to threatening expressions (i.e., anger), whereas, street-boys showed an incoherent significant vagal withdrawal in response to both positive and non-threatening facial expressions of emotions (i.e., fear, joy and sadness). The prolonged exposure to maltreatment and neglect seem to exacerbate vagal suppression in response to non-threatening stimuli, promoting defensive strategies to external social stimuli. In this context, a significant relation among Age and RSA suppression values in response to all facial expressions is expected.

V.b Method

Participants

A total of 73 underage participants were involved in the study, of these 36 belonged to Street (ST) group and 37 were included in the Control (Con) group. All participants filled an anamnestic questionnaire through which their demographic information (i.e., sex, age, schooling, main language, ethnicity), actual and past life and health conditions (i.e., housing detail, necessities goods, history of tropical and infective pathologies, medical treatment), their socio-economic status (i.e., individual or family members' income, occupation and education) and critical life events (i.e., sexual violence, physical violence, abuse, neglect, maltreatment, mourning) were obtained. Partial or unclear information was completed and checked thanks to sanitary, educational or charitable institutions. People who suffered from cardio-respiratory or psychiatric diseases and those who used drugs interfering with the cardio-respiratory activity were excluded from the sampling.

The ST group consisted of street-boys recruited directly in the street, in schools enrolling children without a family or in minor penitentiary institutions. They were all males aged 5 to 17 years (mean age: 11.94, SE 0.72). All ST group participants were abandoned from their parents before the age of 5, time from which they lived in the street without responsible adult care. Because of their life conditions they were exposed to prolonged neglect and to extremely poor socio-economic conditions. They had and have limited access to basic resources (e.g., adequate food, shelter, clothing, and medical care) and they act or suffer high level of maltreatment, intimidation, robberies, and sexual or physical assaults in the street. Hence, among ST group participants, 80% was exposed to physical violence, 40.6% fell victim of sexual violence, and 27% had suffered both physical and sexual violence.

As ST, Con participants, were all males aged 5 to 17 years (mean age: 12.65, SE 0.69), but they had never been street-boys, they lived with their parents or close relatives and they were recruited in primary and secondary private schools. They had and have an adequate access to basic needs, they regularly attended school and they were exposed to low level of maltreatment or abuse. Among Con participants, only 8% referred to be victim of physical violence, whereas nobody reported sexual abuse history.

Living as a street-boy for long time means being exposed to protracted and repetitive experiences of maltreatment and neglect. Because of ST group demographic characteristics (all ST participants were permanently street-boys from the age of 5), age could be an indirect, but efficient, index of trauma exposure time. Age was equally distributed in the two samples (ST: median = 13, Asymmetry = -0.22 SE 0.39, Kurtosis = -1.60 SE 0.77; Con: median = 15, Asymmetry = -0.45 SE 0.39, Kurtosis = -1.52 SE 0.76) with no significant differences between the two groups ($t_{71} = 0.71$, $p = 0.48$).

All participants were literate, with no significant difference between groups in years of schooling (ST: 4.80 SE 3.60; Con: 4.03 SE 2.86; $t_{65} = 1.03$, $p = 0.30$).

The lack of validated tests on African underage population and the wide age-range of our sample prevented us to thoroughly assess participants' cognitive and psychological qualities. Despite this consideration, in order to control for between groups differences in participants' naming skills, the Boston Naming Test (BNT) (Kaplan et al., 1983) was submitted to all participants. BNT assesses visual naming ability and word retrieval through 60 line drawings graded in difficulty and frequency. BNT was chosen thanks to its quick and easy administration, because it is administered to children as well as to young adults, and because it is translated in many languages and already used in many African countries. The two groups did not significantly different in BNT performance (ST: 18.79 SE 8.81; Con: 20.32 SE 5.98; $t_{71} = -0.93$, $p = 0.36$).

Procedure

The experimental session consisted in the same experiments described in Ardizzi et al., (2013) and here described in Chapter II. The employed stimuli were 64 video-morphing constructed from the Montreal Facial Displays of Emotion stimulus set (Beaupre, 2005) depicting the transition from a neutral facial expression to an emotional one (16 anger, 16 fear, 16 joy and 16 sadness). The facial expressions of emotions depicted in the video morphing were modelled by Asian, African, Hispanic and Caucasian actors balanced for gender (4 stimuli for each ethnic group, 2 males and 2 females). Each stimulus lasted 3000 msec (15 fps; 8006560 pixels) and was presented using EPrime 2.0 software (Psychology Software Tools, Inc.).

The order of execution of the behavioral and the physiological experiments was balanced between participants. The experimental setting was maintained the same for behavioral and physiological experiments. The presence of a local social assistant was always guaranteed to ensure that participants remained at ease, understood the instructions and to translate from English to Krio, if necessary.

Behavioral experiment: participants performed a forced-choice facial emotion recognition task during which they were asked to verbally identify, with no time limit, which of the four alternative labels (anger, fear, joy, sadness) best described the emotion expressed in the stimulus. The four alternative labels, written in English and Krio, were always visible. Stimulus presentation was preceded by the question ''you able du am?'' (i.e. ''Are you ready?'') on the monitor. After participant's affirmative answer the experimenter pressed the spacebar to show the successive stimulus. Stimuli were presented once (64 trials, 16 trials for each emotion: anger, fear, joy and sadness) in random order. The behavioral experiment lasted approximately 15 min.

Physiological experiment: to avoid possible confounding effects of caffeine, tobacco and alcohol on physiological measures, participants were required to abstain from those substances for 2 hours prior to the experiment (Ardizzi et al., 2013). Participants were asked to carefully observe the stimuli, while physiological responses were recorded. The physiological experiment consisted of four ''condition-blocks'' (each lasting 192 sec) and two ''baseline blocks''(each lasting 120 sec). The four ''condition-blocks'', one for each emotional condition (anger, fear, joy and sadness), were randomly presented. Inside each ''condition-block'' the sixteen stimuli, comprising the same emotion, were randomly presented three times (48 trials). Each stimulus was preceded by a fixation cross lasting one second. The two ''baseline-blocks'', consisting of a black centered fixation cross on gray background, were performed one before (Baseline) and one after (Recovery) the four ''condition-blocks''. In order to maintain participants' attention, after each ''condition-block'' the experimenter asked a question about the videos just shown. Participants' faces were video-recorded to ensure that they looked at the screen. Overall the physiological experiment lasted 17 min.

Dependent Measures

Accuracy rate and Anger False Alarms Rate were obtained as dependent measures from participants' performance to Behavioral experiment. Accuracy rate (Acc) was computed as participants' percentage of correct use of each emotion label; Anger False Alarms Rate (Afa) was calculated as participants' percentage of incorrect use of anger label during forced-choice facial emotion recognition task. Afa represents the behavioral expression of a possible anger recognition bias, as reflecting the over-attribution of anger label to non-anger facial expressions of emotions (e.g., anger attribution to fear, sadness and joy facial expressions).

For the entire duration of Physiological experiment two physiological measures were recorded: Facial electromyography (EMG) and Respiratory Sinus Arrhythmia (RSA).

Facial EMG - 4 mm Ag/Ag-Cl electrodes were bipolarly placed on the left side of the face over Corrugator Supercilii and Zygomaticus Major muscle regions (Fridlund & Cacioppo, 1986). Participants' skin was cleaned and prepared by alcohol solution and the electrodes were filled with gel conductive paste. Facial EMG were sampled at 2 kHz and recorded with an online Mains Filter (adaptive 50 Hz filter). A 20–500 Hz band-pass filter (van Boxtel, 2001) was applied offline on the raw facial EMG signal. EMG signals were screened for artifacts by a blind coder who firstly deleted trials with artifacts due to electrical noise (less than 3.5% of removed trials), and subsequently, who inspected participants' faces video to remove trials affected by motion artifacts (i.e., a variety of facial movements not directly related to stimuli observation but affecting the EMG signal like cough, sneeze, yawn). No participants presented more than 30% of discarded trials. Following standard practice, the average amplitude of EMG signal was obtained via root-mean-square method. EMG response (expressed in microvolts, μV) was computed, independently for the two muscles, as the mean change score between activity during each 500 msec of the 3 sec stimulus period and the 500 msec of the fixation cross immediately preceding stimulus onset (Fridlund & Cacioppo, 1986). Following this procedure the mean activations of Corrugator Supercilii and Zygomaticus Major muscles during the visualization of angry, fear, joy and sadness facial expressions were obtained.

RSA - ECG was recorded to extract participants' RSA, using three 10 mm Ag/AgCl pre-gelled electrodes (ADInstruments, UK) placed in an Einthoven's triangle configuration. The ECG was sampled at 1 kHz and online filtered with the Mains Filter. The peak of the R-wave of the ECG was detected from each sequential heartbeat. The R-R intervals were extracted and the artifacts edited by integer division or summation (Berntson et al., 1997). Editing consisted of visual detection of outlier points, typically caused by failure to detect an R-peak (e.g., edit via division) or faulty detections of two or more ''peaks'' within a period representing the R-R interval (e.g., edit via summation). The amplitude of RSA was quantified with CMetX (available from http://apsychoserver.psych.arizona.edu) that produces data with a correlation near the unity with those obtained using Boher & Porges method (Allen et al., 2007). The amplitude of RSA [expressed in $\ln(\text{msec})^2$] was calculated as the variance of heart rate activity across the band of frequencies associated with spontaneous respiration (0.12–0.40 Hz). RSA was extracted for the entire duration of each "condition-block" and each "baseline-block", according to guidelines (Berntson et al., 1997). To assure an homogeneous computation of RSA amplitude this procedure was conducted on consecutive epochs lasting 30 sec both for Baseline, Recovery and for each condition-block. Hence, the Baseline and Recovery RSA values resulted from the average of 4 consecutive epochs, whereas the condition-blocks RSA values were calculated as the mean of 6 consecutive epochs. The RSA response values, for each condition-block, were measured as change scores between condition-block RSA values and Baseline RSA value.

Overall, dependent measures obtained from behavioral (Table 4-A) and physiological (Table 4-B) experiments and entered in the following described statistical analyses (see paragraph IV.b - Statistical analyses sub-session) were: participants' Accuracy rate, Anger False Alarms rate and Corrugator, Zygomaticus and RSA responses during the four emotions visualization. Finally, also RSA values at Baseline and Recovery were recorded and employed as dependent measures.

A	**Behavioral Experiment**						
		Accuracy rate (Acc) Anger False Alarms rate (Afa)					
B	**Physiological Experiment**	Baseline	Recovery	Anger	Fear	Joy	Sadness
	Corrugator Supercilii Activity			x	x	x	x
	Zygomaticus Major Activity			x	x	x	x
	Respiratory Sinus Arrhythmia (RSA)	x	x	x	x	x	x

Table 4: Dependent measures resulting from Behavioral (A) and Physiological (B) experiments.

Statistical Analyses

To investigate impact trajectories of trauma exposure on emotion recognition and physiological measures, 32 curve estimation analyses, two for each dependent measure, were conducted separately for the two groups (ST and Con groups). Participants' age was entered as predictor, considering it as an indirect index of trauma exposure. Curve estimation analysis was conducted because both linear and non-linear relations between age and dependent measures could be expected. Three curve models (linear, logarithmic and quadratic) were estimated. Among significant curve models (ANOVAs $p < 0.05$), the curve with the highest R^2 and significant coefficients (coefficient $p < 0.05$) was selected as best representative. For each curve estimation model a summary table with statistics information was reported.

Between groups differences in emotion recognition were estimated by means of two independent sample (two-tailed) t-tests comparing ST and Con Acc and Afa, respectively.

To evaluate between groups differences in Facial EMG and RSA responses to facial expressions of emotions, three separate repeated-measures ANOVAs were performed on Corrugator activities, Zygomaticus activities and RSA responses, respectively. In all cases, group (ST and Con) was entered as between factor and Emotion (anger, fear, joy and sadness) was included as within factor. Accordingly to guideline (Girden, 1992), when the sphericity assumption was violated, Geisser–Greenhouse correction was calculated and adjusted df, corrected p values, and epsilon values (Ɛ) reported. Whenever appropriate, significant between and within groups differences were explored performing Tukey post-hoc comparison. Partial eta square (η^2_p) was calculated as effect size measure.

Finally, between groups differences in Baseline and Recovery RSA values were assessed conducting two independent sample (two-tailed) t-tests comparing ST and Con Baseline and Recovery RSA values, respectively.

V.c Results

Behavioral results

Accuracy rate

Curve estimation analyses conducted on Accuracy rate, demonstrated, only for the Con group a significant positive linear relation between age and Accuracy rate. No models resulted significant for the ST group (Table 5 and Figure 20 panel A).

ACC		Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.24	.057	166.594	1	31	166.594	1.89	.179	.240	1.37	.179
	Logarithmic	.27	.073	212.880	1	31	212.880	2.46	.130	.271	1.57	.127
	Quadratic	.30	.093	269.426	2	30	134.713	1.54	.232	1.767 -1.538	1.24 -1.08	.223 .287
Con	**Linear**	**.48**	**.228**	**631.276**	**1**	**34**	**631.276**	**10.02**	**.003***	**.477**	**3.16**	**.003***
	Logarithmic	.47	.225	624.335	1	34	624.335	9.87	.003*	.474	3.14	.003*
	Quadratic	.48	.228	631.760	2	33	315.880	4.87	.014*	.606 -.129	.40 -.09	.688 .932

Table 5: Accuracy rate curve estimation models for ST and Con group. Age: predictor; Accuracy rate: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05

Independent sample t-test comparing ST (58.38% SE 1.66) and Con (76.21% SE 1.48) Accuracy rate resulted significant (T_{67} = -8.04, p>0.0001) (Figure 21 panel A).

Anger False Alarms rate

No Curve estimation analyses conducted on Anger false alarms rate were significant both for ST and Con groups (Table 6 and Figure 20 panel B).

Afa		Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.02	.000	1.573	1	33	1.573	.02	.917	-.018	-.10	917
	Logarithmic	.00	.000	.114	1	33	.114	.00	.987	.005	.03	.978
	Quadratic	.20	.039	184.936	2	32	92.468	.65	.527	1.619 -1.649	1.12 -1.14	.272 .263
Con	Linear	.06	.004	2.357	1	33	2.357	.12	.729	-.061	-.35	.729
	Logarithmic	.07	.004	2.754	1	33	2.754	.14	.708	-.066	-.38	.708
	Quadratic	.06	.004	2.378	2	32	1.189	.06	.942	-.123 .062	-.064 .033	.949 .947

Table 6: Anger false alarm rate curve estimation models for ST and Con group. Age: predictor; Anger False Alarm rate (Afa): dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

Independent sample t-test comparing ST (18.97% SE 2) and Con (7.90% SE 0.73) Anger False Alarms rate resulted significant (T_{68} = 5.22, p>0.0001) (Figure 21 panel B).

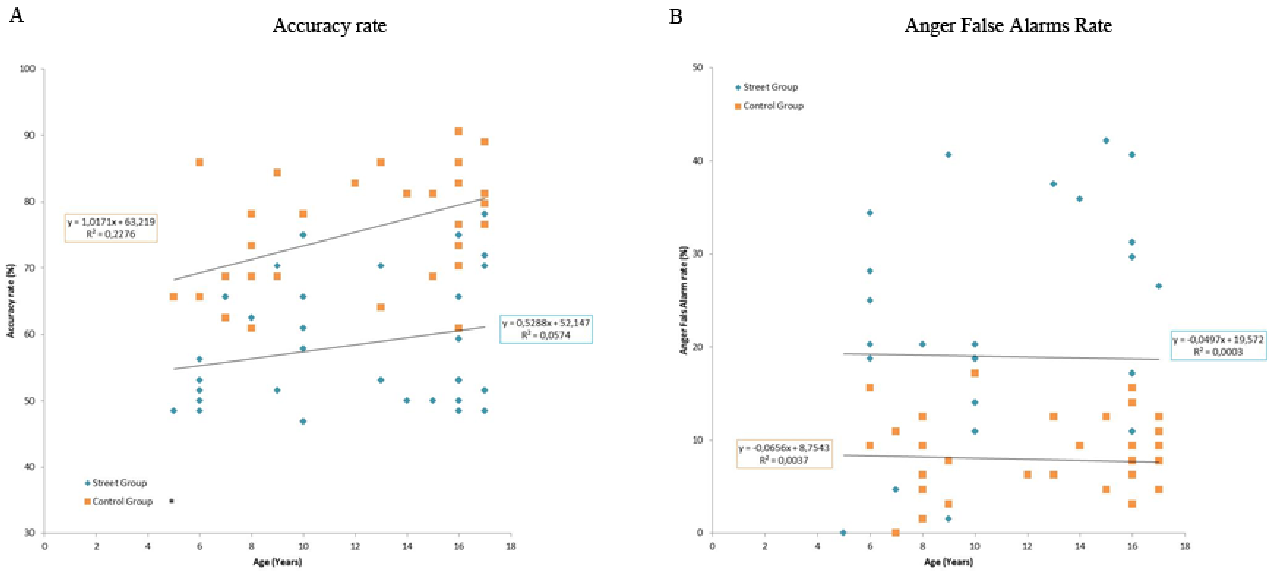

Figure 20 – Panel A: Plot of Age (years) versus Accuracy rate (%) for Street Group and Control Group. Panel B: Plot of Age (years) versus Angry False Alarms rate (%) for Street Group and Control Group. * = $p < 0.05$

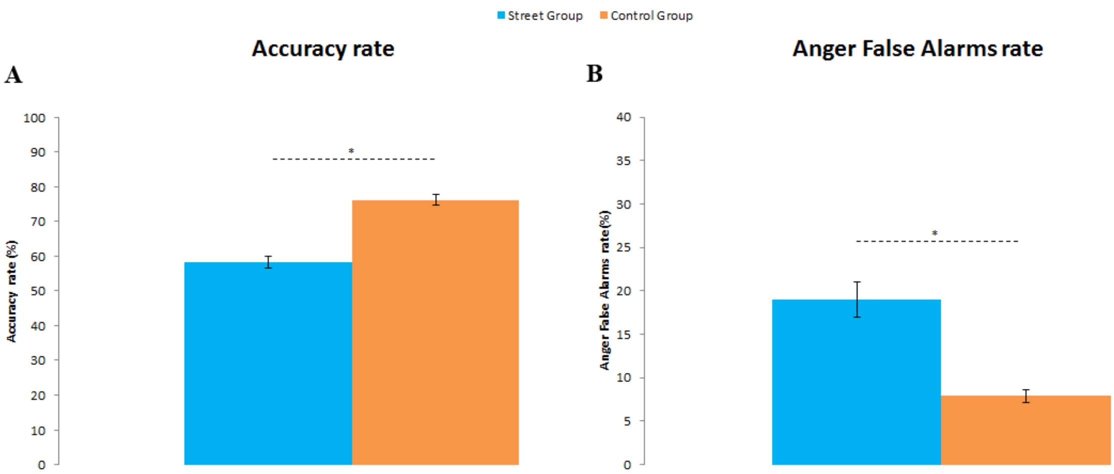

Figure 21 – Panel A: Accuracy rate (%) for Street Group and Control Group. Panel B: Anger False Alarms rate (%) for Street Group and Control Group. * = $p < 0.05$. Error bars represent SE.

Physiological results

Angry facial expression

Curve estimation analyses conducted on Corrugator activity to angry facial expressions, demonstrated, only for the ST group a significant negative linear relation between age and muscle activation. No models resulted significant for the Con group (Table 7 and Figure 22 panel A).

Anger	**Corrugator**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	**Linear**	**.48**	**.234**	**2.133**	**1**	**30**	**2.133**	**9.19**	**.005***	**-.484**	**-3.03**	**.005***
	Logarithmic	.48	.231	2.101	1	30	2.101	9.01	.005*	-.481	-3.00	.005*
										-1.030	-.734	.469
	Quadratic	.48	.238	2.170	2	29	1.085	4.54	.019*	.549	.391	.698
Con	Linear	.13	.016	.148	1	30	.148	.496	.487	-.128	-.704	.487
	Logarithmic	.11	.013	.121	1	30	.121	.404	.530	-.115	-.636	.530
										.394	.215	.832
	Quadratic	.14	.019	.174	2	29	.087	.281	.757	-.524	-.286	.777

Table 7: Corrugator response to Anger curve estimation models for ST and Con group. Age: predictor; Corrugator response to Anger: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = $p < .05$.

Curve estimation analyses conducted on Zygomaticus activity to angry facial expressions, demonstrated, only for the ST group a significant positive linear relation between age and muscle activation. No models resulted significant for the Con group (Table 8 and Figure 22 panel B).

Anger	**Zygomaticus**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	**Linear**	**.40**	**.162**	**4.387**	**1**	**28**	**4.387**	**5.42**	**.027***	**.403**	**2.33**	**.027*.**
	Logarithmic	.39	.155	22.852	1	28	4.194	5.14	.031*	.394	2.27	.031*
										.407	.25	.801
	Quadratic	.40	.162	4.387	2	27	2.194	2.61	.092	-.004	-.00	.998
Con	Linear	.14	.020	.276	1	29	.276	.60	.444	-.143	-.78	.444
	Logarithmic	.13	.017	.235	1	29	.235	.51	.481	-.132	-.71	.481
										1.490	.72	.476
	Quadratic	.20	.042	.569	2	28	.285	.61	.549	-1.639	-.79	.434

Table 8: Zygomaticus response to Anger curve estimation models for ST and Con group. Age: predictor; Zygomaticus response to Anger: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = $p < .05$.

Curve estimation analyses conducted on RSA response to angry facial expressions, demonstrated, only for the ST group a significant negative linear relation between age and autonomic modulation. No models resulted significant for the Con group (Table 9 and Figure 22 panel C).

Anger	**RSA**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	**Linear**	**.37**	**.138**	**.947**	**1**	**32**	**.947**	**5.11**	**.031***	**-.371**	**-2.26**	**.031***
	Logarithmic	.37	.137	.945	1	32	.945	5.09	.031*	-.371	-2.26	.031*
										-.471	-.33	.744
	Quadratic	.37	.138	.948	2	31	.474	2.48	.100	.101	.07	.944
Con	Linear	.12	.014	.105	1	33	.105	.47	.496	-.119	-.69	.496
	Logarithmic	.13	.018	.130	1	33	.130	.59	.448	-.132	-.77	.448
										-1.619	-.96	.346
	Quadratic	.19	.038	.283	2	32	.141	.63	.538	1.508	.89	.379

Table 9: RSA response to Anger curve estimation models for ST and Con group. Age: predictor; RSA response to Anger: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

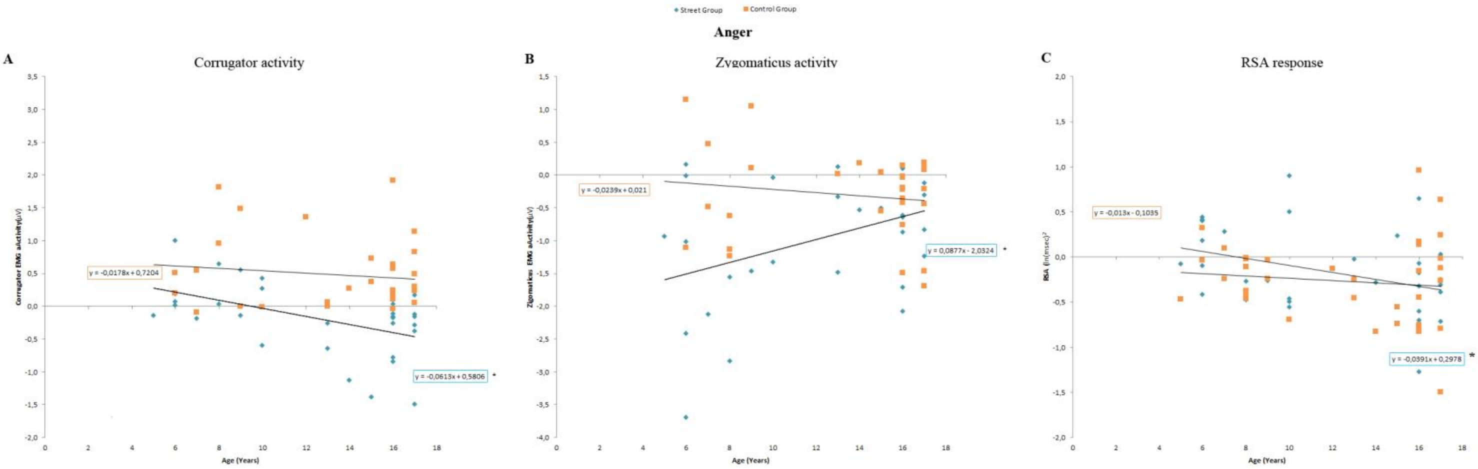

Figure 22 – Panel A: Plot of Age (years) versus Corrugator EMG Activity to angry facial expressions (μV) for Street Group and Control Group. Panel B: Plot of Age (years) versus Zygomaticus EMG Activity to angry facial expressions (μV) for Street Group and Control Group. Panel C: Plot of Age (years) versus RSA response to angry facial expressions [ln(msec)2] for Street Group and Control Group. Rectangles show estimated lines equations. * = p < 0.05.

Fear facial expression

Curve estimation analyses conducted on Corrugator activity to fear facial expressions, demonstrated, only for the ST group a significant negative linear relation between age and muscle activation. No models resulted significant for the Con group (Table 10 and Figure 23 panel A).

Fear	**Corrugator**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	**Linear**	**.43**	**.186**	**3.855**	**1**	**30**	**3.855**	**6.87**	**.014***	**-.432**	**-2.62**	**.14***
	Logarithmic	.43	.183	3.776	1	30	3.776	6.70	.015*	-.427	-2.59	.015*
	Quadratic	.43	.186	3.856	2	29	1.928	3.32	.05*	-.478 .047	-.32 .03	.749 .975
Con	Linear	.28	.081	.906	1	28	.906	2.48	.127	-.285	-1.57	.127
	Logarithmic	.30	.092	1.023	1	28	1.023	2.83	.10	-.303	-1.68	.104
	Quadratic	.35	.122	1.356	2	27	.687	1.87	.174	-2.282 2.007	-1.27 1.11	.22 .27

Table 10: Corrugator response to Fear curve estimation models for ST and Con group. Age: predictor; Corrugator response to Fear: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

No Curve estimation analyses conducted on Zygomaticus activity to fear facial expressions were significant both for ST and Con groups (Table 11 and Figure 23 panel B).

Fear	**Zygomaticus**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.03	.001	.016	1	29	.016	.02	.884	.027	.15	.884
	Logarithmic	.06	.003	.070	1	29	.070	.10	.757	.058	.31	.757
	Quadratic	.17	.029	.617	2	28	.308	.42	.659	1.520 -1.520	.92 -.91	.365 .371
Con	Linear	.09	.009	.694	1	30	.694	.26	.611	.094	.51	.611
	Logarithmic	.05	.002	.188	1	30	.188	.07	.792	.049	.27	.792
	Quadratic	.38	.147	11.643	2	29	5.821	2.49	.100	-3.672 3.784	-2.10 2.17	.044* .039*

Table 11: Zygomaticus response to Fear curve estimation models for ST and Con group. Age: predictor; Zygomaticus response to Fear: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

No Curve estimation analyses conducted on RSA response to fear facial expressions were significant both for ST and Con groups (Table 12 and Figure 23 panel C).

Fear	RSA	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.29	.086	.785	1	32	.785	3.00	.093	-.293	1.73	.093
	Logarithmic	.30	.092	.843	1	32	.843	3.24	.081	-.303	-1.80	.081
										-1.503	-1.03	.311
	Quadratic	.32	.106	.969	2	31	.484	1.83	.176	1.219	.83	.410
Con	Linear	.21	.046	.451	1	33	.451	1.60	.215	-.215	-1.26	.215.21
	Logarithmic	.21	.049	.474	1	33	.474	1.69	.203	-.221	-1.30	.203
										-1.240	-.74	.464
	Quadratic	.24	.057	.560	2	32	.280	.97	.388	1.031	.61	.453

Table 12: RSA response to Fear curve estimation models for ST and Con group. Age: predictor; RSA response to Fear: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = $p < .05$.

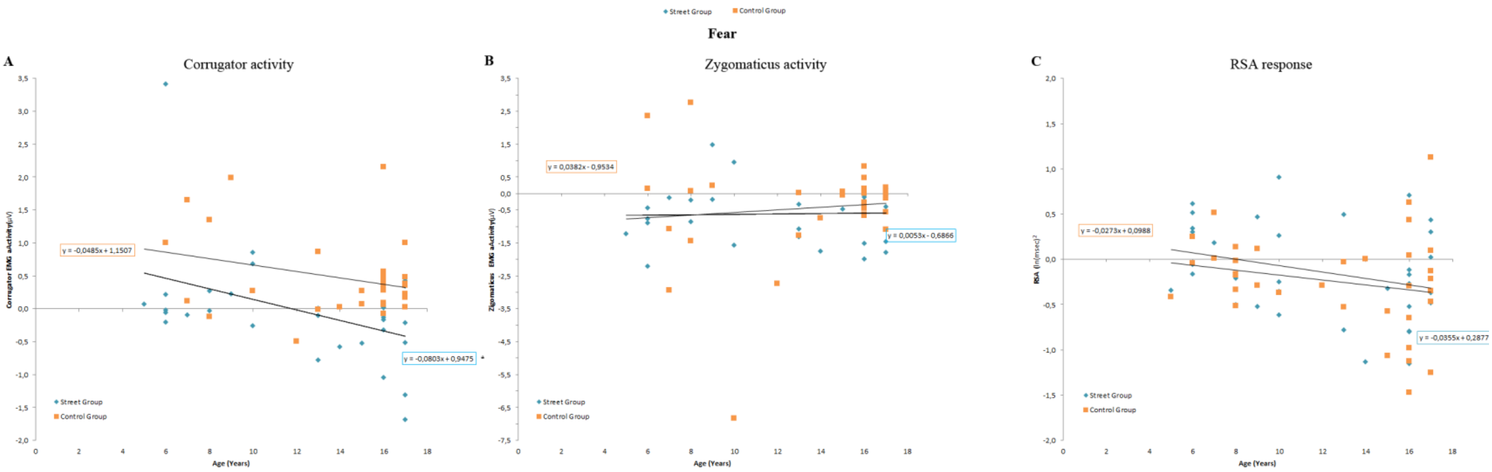

Figure 23 – Panel A: Plot of Age (years) versus Corrugator EMG Activity to fear facial expressions (μV) for Street Group and Control Group. Panel B: Plot of Age (years) versus Zygomaticus EMG Activity to fear facial expressions (μV) for Street Group and Control Group. Panel C: Plot of Age (years) versus RSA response to fear facial expressions [ln(msec)2] for Street Group and Control Group. Rectangles show estimated lines equations. * = $p < 0.05$.

Joy facial expression

No Curve estimation analyses conducted on Corrugator activity to joy facial expressions were significant both for ST and Con groups (Table 13 and Figure 24 panel A).

Joy	**Corrugator**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.32	.103	.329	1	30	.329	3.34	.078	-.321	-1.83	.078
	Logarithmic	.35	.122	.388	1	30	.388	4.02	.054	-.349	-2.00	.054
										-2.074	1.38	.179
	Quadratic	.38	.145	.462	2	29	.231	2.40	.111	1.764	1.17	.251
Con	Linear	.10	.010	.060	1	30	.060	.30	.587	.100	.55	.587
	Logarithmic	.10	.009	.056	1	30	.056	.28	.598	.097	.53	.598
										.025	.01	.989
	Quadratic	.10	.010	.060	2	29	.030	.15	.865	.075	.04	.968

Table 13: Corrugator response to Joy curve estimation models for ST and Con group. Age: predictor; Corrugator response to Joy: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

No Curve estimation analyses conducted on Zygomaticus activity to joy facial expressions were significant both for ST and Con groups (Table 14 and Figure 24 panel B).

Joy	**Zygomaticus**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.00	.000	.001	1	29	.001	.00	.980	-.005	-.02	.980
	Logarithmic	.00	.000	.003	1	29	.003	.00	.966	.008	.04	.966
										.303	.18	.861
	Quadratic	.03	.001	.056	2	28	.028	.02	.984	-.309	-.18	.859
Con	Linear	.14	.020	2.977	1	30	2.977	.60	.445	-.140	-.77	.445
	Logarithmic	.10	.011	1.730	1	30	1.730	.34	.562	-.107	-.59	.562
										2.921	1.64	.112
	Quadratic	.33	.111	16.868	2	29	8.434	1.80	.182	-3.076	-1.72	.095

Table 14: Zygomaticus response to Joy curve estimation models for ST and Con group. Age: predictor; Zygomaticus response to Joy: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

No Curve estimation analyses conducted on RSA response to joy facial expressions were significant both for ST and Con groups (Table 15 and Figure 24 panel C).

Joy	**RSA**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.22	.048	.372	1	31	.372	1.57	.220	-.220	-1.25	.220
	Logarithmic	.24	.058	.448	1	31	.448	1.91	.177	-.241	-1.38	.177
										-1.928	-1.34	.190
	Quadratic	.30	.092	.708	2	30	.354	1.51	.236	1.721	1.20	.240
Con	Linear	.07	.004	.054	1	34	.054	.15	.701	.066	.39	.701
	Logarithmic	.08	.007	.448	1	34	.448	1.91	.177	.081	.47	.639
										.628	.37	.714
	Quadratic	.08	.008	.095	2	33	.047	.13	.880	-.565	-.33	.741

Table 15: RSA response to Joy curve estimation models for ST and Con group. Age: predictor; RSA response to Joy: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

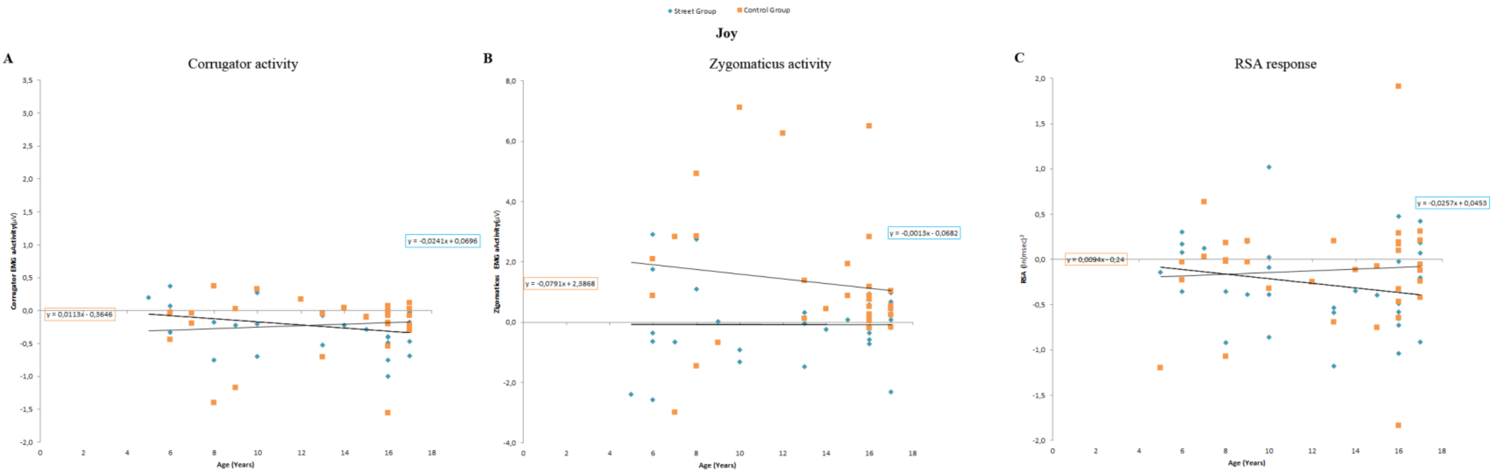

Figure 24 – Panel A: Plot of Age (years) versus Corrugator EMG Activity to joy facial expressions (µV) for Street Group and Control Group. Panel B: Plot of Age (years) versus Zygomaticus EMG Activity to joy facial expressions (µV) for Street Group and Control Group. Panel C: Plot of Age (years) versus RSA response to joy facial expressions [ln(msec)2] for Street Group and Control Group. Rectangles show estimated lines equations. * = p < 0.05.

Sadness facial expression

Curve estimation analyses conducted on Corrugator activity to sadness facial expressions, demonstrated, only for the ST group a significant negative logarithmic relation between age and muscle activation. No models resulted significant for the Con group (Table 16 and Figure 25 panel A).

Sadness	**Corrugator**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.46	.216	2.449	1	30	2.449	8.28	.007*	-.465	-2.88	.007*
	Logarithmic	**.47**	**.225**	**2.549**	**1**	**30**	**2.549**	**8.72**	**.006***	**-.474**	**-2.95**	**.006***
	Quadratic	.48	.228	2.581	2	29	1.291	4.28	.023*	-1.396 .937	-.10 .66	.331 .512
Con	Linear	.11	.013	.159	1	29	.159	.38	.541	-.114	-.62	.541
	Logarithmic	.14	.019	.227	1	29	.227	.55	.465	-.136	-.74	.465
	Quadratic	.25	.061	.743	2	28	.371	.91	.415	-2.553 2.448	-1.25 1.19	.223 .242

Table 16: Corrugator response to Sadness curve estimation models for ST and Con group. Age: predictor; Corrugator response to Sadness: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

No Curve estimation analyses conducted on Zygomaticus activity to sadness facial expressions were significant both for ST and Con groups (Table 17 and Figure 25 panel B).

Sadness	**Zygomaticus**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.02	.001	.017	1	29	.017	.02	.90	.024	.13	.898
	Logarithmic	.05	.003	.083	1	29	.083	.08	.779	.052	.28	.779
	Quadratic	.20	.040	1.217	2	28	.608	.59	.561	1.748 -1.736	1.07 -1.08	.287 .290
Con	Linear	.00	.000	.000	1	28	.000	.00	.992	.002	.01	.992
	Logarithmic	.01	.000	.000	1	28	.000	.00	.975	.006	.03	.975
	Quadratic	.05	.002	.012	2	27	.006	.03	.970	.545 -.545	.25 -.25	.807 .806

Table 17: Zygomaticus response to Sadness curve estimation models for ST and Con group. Age: predictor; Zygomaticus response to Sadness: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

Curve estimation analyses conducted on RSA response to sadness facial expressions, demonstrated, only for the ST group a significant quadratic relation between age and autonomic modulation. No models resulted significant for the Con group (Table 18 and Figure 25 panel C).

Sadness	**RSA**	Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.24	.057	.469	1	33	.469	1.99	.167	-.239	-1.41	.167
	Logarithmic	.28	.078	.643	1	33	.643	2.80	.104	-.280	-1.67	.104
										-3.138	**-2.34**	**.026***
	Quadratic	**.42**	**.179**	**1.472**	**2**	**32**	**.736**	**3.49**	**.043***	**2.920**	**2.18**	**.037***
Con	Linear	.30	.092	.481	1	33	.481	3.36	.076	-.304	-1.83	.076
	Logarithmic	.29	.087	.453	1	33	.453	3.15	.085	-.295	-1.77	.085
										-.808	-.49	.624
	Quadratic	.31	.095	.495	2	32	.247	1.68	.202	.506	.31	.758

Table 18: RSA response to Sadness curve estimation models for ST and Con group. Age: predictor; RSA response to Sadness: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

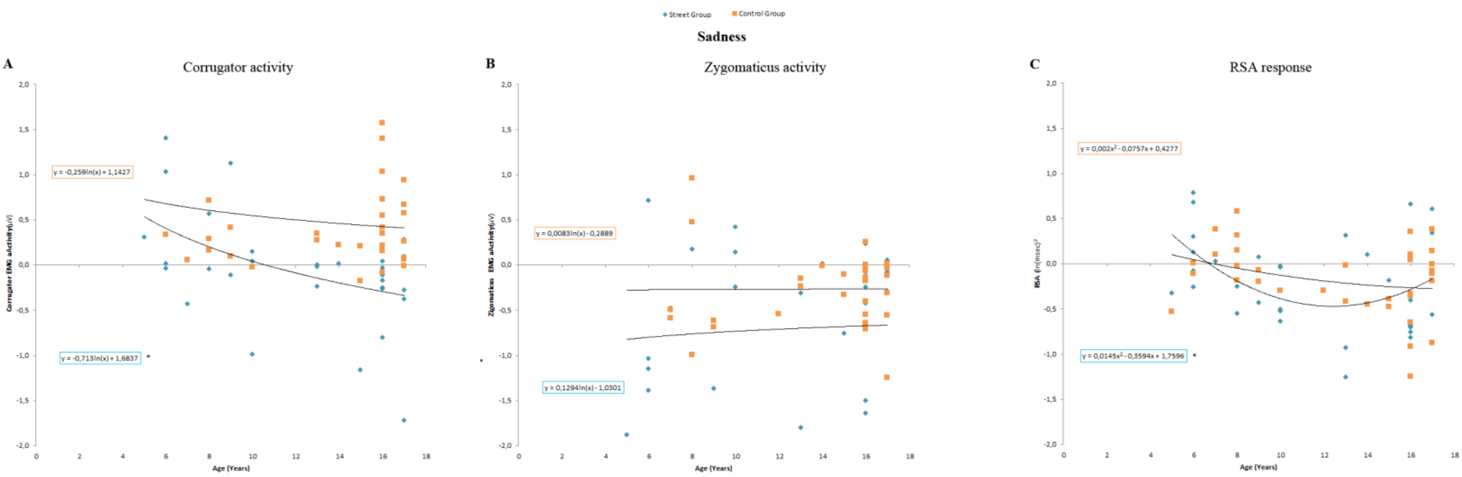

Figure 25 – Panel A: Plot of Age (years) versus Corrugator EMG Activity to sadness facial expressions (μV) for Street Group and Control Group. Panel B: Plot of Age (years) versus Zygomaticus EMG Activity to sadness facial expressions (μV) for Street Group and Control Group. Panel C: Plot of Age (years) versus RSA response to sadness facial expressions [ln(msec)2] for Street Group and Control Group. Rectangles show estimated curve equations. * = p < 0.05.

Repeated-measures ANOVA conducted on Corrugator EMG activity revealed a significant main effect of the factors Group ($F_{1,55} = 24.51$, $p < 0.0001$; $\eta^2_p = 0.31$) and Emotion ($F_{3,55} = 10.18$, $p < 0.0001$; $\eta^2_p = 0.16$) as well as a significant interaction Emotion by Group ($F_{3,55} = 5.30$, $p < 0.001$; $\eta^2_p = 0.09$).

Post-hoc comparisons conducted on the main effect of Group revealed that ST (-0.17 µV, SE 0.06) had significantly lower Corrugator activity than Con (0.29 µV, SE 0.07) ($p < 0.0001$). Post-hoc analyses performed on Emotion main effect showed that Corrugator EMG activity recorded in response to joy facial expressions (-0.20 µV, SE 0.04) was significantly lower than Corrugator activities measured in response to all other negative facial expressions (anger: 0.07 µV, SE 0.06; fear 0.17 µV, SE 0.07; sadness: 0.20 µV, SE 0.08) (all $p_s < 0.05$). Finally, post-hoc comparisons executed on Emotion by Group interaction (Figure 26) demonstrated that ST Corrugator activities to fear (-0.16 µV, SE 0.10) and sadness (-0.09 µV, SE 0.11) facial expressions were significantly lower than those recorded from Con group (fear: 0.50 µV, SE 0.11; sadness: 0.49 µV, SE 0.12) (all $p_s < 0.05$). Considering within group differences in Corrugator activation among different facial expressions of emotions, only Con group showed significant lower activation to joy facial expression (-0.16 µV, SE 0.06) compared to all other facial expressions of emotions (anger: 0.34 µV, SE 0.09; fear: 0.50 µV, SE 0.11; sadness: 0.49 µV, SE 0.12) (all $p_s < 0.05$). On the contrary among ST participants, Corrugator activity resulted not significantly modulated in response to positive and negative facial expressions (anger: -0.20 µV, SE 0.09; fear -0.16 µV, SE 0.10; joy: -0.24 µV, SE 0.06; sadness: -0.09 µV, SE 0.11) (all $p_s > 0.05$).

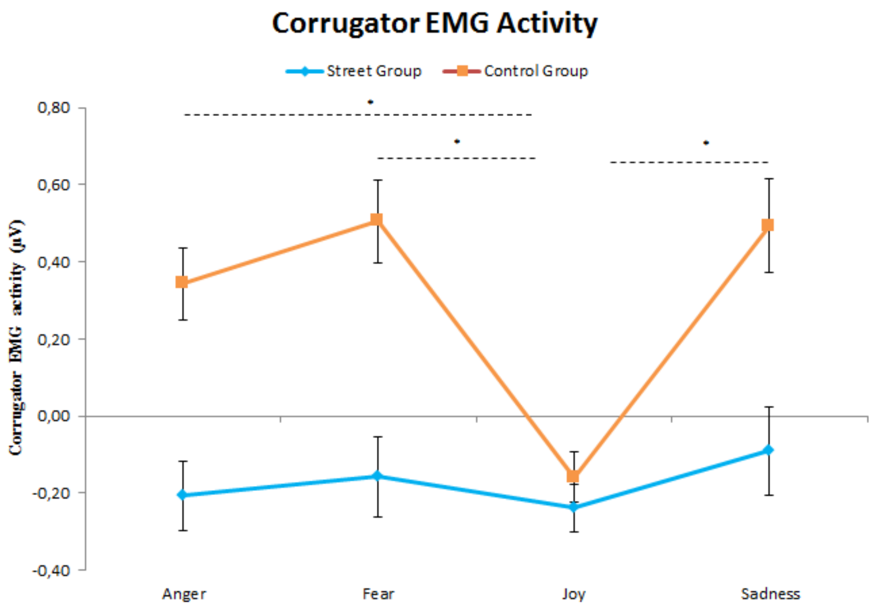

Figure 26: Corrugator EMG Activity for Street Group and Control Group during presentation of emotional facial expressions. * = p < 0.05. Error bars represent SE.

Mauchly's test conducted on Zygomaticus EMG activity showed a violation of sphericity assumption for Emotion ($\chi^2_{(5)} = 42.87$, $p < 0.001$). Hence degrees of freedom were adjusted using Greenhouse-Geisser correction ($\mathcal{E} = 0.66$). Repeated-measures ANOVA conducted on Zygomaticus EMG activity revealed a significant main effect of the factors Group ($F_{1,54} = 12.95$, $p < 0.001$; $\eta^2_p = 0.19$) and Emotion ($F_{1.98,106.93} = 14.31$, $p < 0.0001$; $\eta^2_p = 0.21$).

Post-hoc comparisons conducted on the main effect of Group revealed that ST (-0.62 µV, SE 0.12) had significantly lower Zygomaticus activity than Con (0.01 µV, SE 0.12) ($p < 0.001$). Post-hoc analyses performed on Emotion main effect showed that Zygomaticus EMG activity recorded in response to joy facial expressions (0.40 µV, SE 0.20) was significantly higher than Zygomaticus activities measured in response to all other negative facial expressions (anger: -0.66 µV, SE 0.11; fear -0.43 µV, SE 0.11; sadness: -0.51 µV, SE 0.10) (all $p_s < 0.0001$).

Repeated-measures ANOVA conducted on RSA response did not show either significant main effects of Group ($F_{1,63} = 0.32$, $p = 0.86$; $\eta^2_p = 0.001$) and Emotion ($F_{1,63} = 1.32$, $p = 0.25$; $\eta^2_p = 0.02$) or significant interaction ($F_{1,63} = 3.15$, $p = 0.08$; $\eta^2_p = 0.05$).

Baseline RSA

Curve estimation analyses conducted on Baseline RSA response to sadness facial expressions, demonstrated, only for the ST group a significant quadratic relation between age and autonomic modulation. No models resulted significant for the Con group (Table 19 and Figure 27 panel A).

Baseline RSA		Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.04	.002	.102	1	33	.102	.05	.815	.041	.24	.815
	Logarithmic	.10	.009	.560	1	33	.560	.31	.584	.096	.55	.584
	Quadratic	**.43**	**.185**	**11.282**	**2**	**32**	**5.641**	**2.64**	**.038***	**3.714** **-3.698**	**2.70** **-2.68**	**.011*** **.011***
Con	Linear	.05	.003	.066	1	33	.066	.08	.774	-.05	-2.9	.774
	Logarithmic	.09	.007	.191	1	33	.191	.24	.625	-.086	-.49	.625
	Quadratic	.31	.098	2.560	2	32	1.280	1.74	.192	-3.029 2.995	-1.86 1.84	.072 .075

Table 19: Baseline RSA curve estimation models for ST and Con group. Age: predictor; Baseline RSA: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

Independent sample t-test comparing ST (5.76 $\ln(\text{msec})^2$, SE 1.34) and Con (6.16 $\ln(\text{msec})^2$, SE 0.88) Baseline RSA resulted not significant ($T_{58.64} = 1.44$, $p = 0.15$).

Recovery RSA

No Curve estimation analyses conducted on Recovery RSA were significant both for ST and Con groups (Table 20 and Figure 27 panel B).

Recovery RSA		Model Summary		ANOVA						Coefficient		
		R	R^2	SS	df1	df2	MS	F	Sig.	beta	t	Sig.
ST	Linear	.05	.002	.075	1	29	.075	.07	.791	-.05	-.27	.791
	Logarithmic	.03	.001	.034	1	29	.034	.03	.859	-.033	-.18	.859
	Quadratic	.17	.030	.921	2	28	.460	.43	.652	1.451 -1.510	.859 -.893	.398 .397
Con	Linear	.02	.000	.007	1	32	.007	.01	.927	-.02	-.09	.927
	Logarithmic	.04	.002	.047	1	32	.047	.06	.814	-.042	-.24	.814
	Quadratic	.27	.075	2.015	2	31	1.007	1.26	.297	-2.670 2.668	-1.60 1.60	.122 .123

Table 20: Recovery RSA curve estimation models for ST and Con group. Age: predictor; Recovery RSA: dependent measure. SS: Sum of Squares, df: Degree of Freedom; MS: Mean sum of Squares. * = p < .05.

Independent sample t-test comparing ST (5.98 $\ln(msec)^2$, SE 1.01) and Con (6.23 $\ln(msec)^2$, SE 0.15) Recovery RSA resulted not significant (T_{63} = 1.45, p = 0.15).

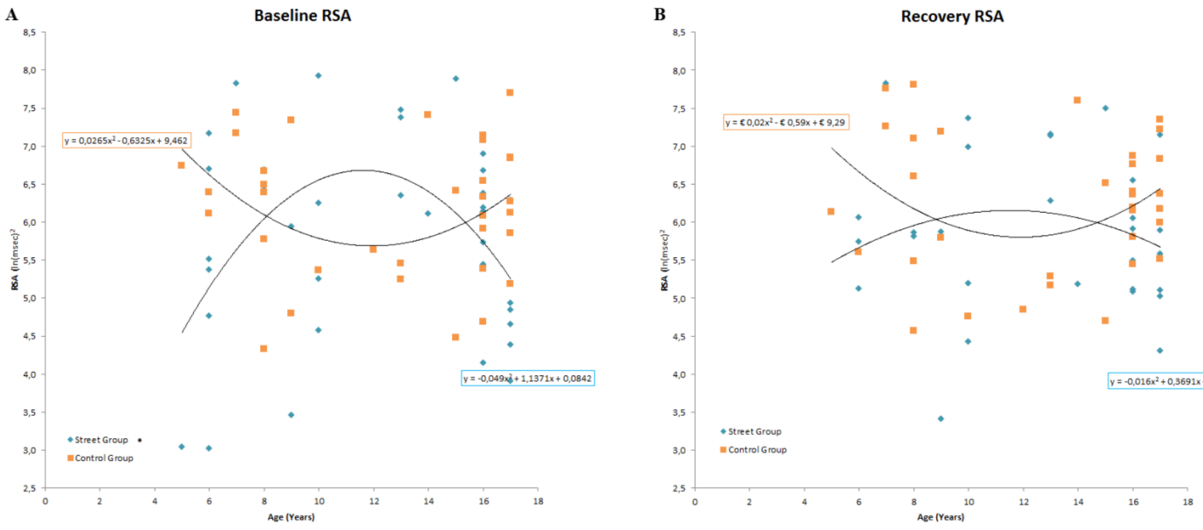

Figure 27 – Panel A: Plot of Age (years) versus Baseline RSA value [ln(msec)2] for Street Group and Control Group. Panel B: Plot of Age (years) versus Recovery RSA value [ln(msec)2] for Street Group and Control Group. Rectangles show estimated curve equations. * = p < 0.05

V.d Discussion

The aim of the present study was to evaluate impact trajectories of prolonged experiences of maltreatment and neglect on the recognition of facial expressions of emotions, Facial Mimicry and vagal regulation. To this aim a group of street-boys (age range 5-17 years) and an age-matched control group performed a forced-choice facial expressions recognition task, as well as, a facial expressions perceptual task during which facial EMG activities and RSA responses were recorded. To assess the impact of prolonged experiences of maltreatment and neglect, participants' age was used as index of trauma exposure.

As expected, the analysis of participants' performance at the forced-choice facial expressions recognition task demonstrated a significant lower Accuracy rate and a higher Anger False Alarms rate among street-boys with respect to controls. These results confirmed that prolonged exposure to maltreatment and neglect alters victims' facial expressions of emotions recognition and induces a bias in angry facial expressions recognition, as previously demonstrated by a wide range of studies (Ardizzi et al., 2013; Fries & Pollak, 2004; Pollak et al., 2000, 2009; Pollak & Kistler, 2002; Pollak & Sinha, 2002). Our results extend these conclusions on the specific influence of trauma exposure on explicit facial expressions recognition. Only control participants showed the expected linear increase with age of facial expressions recognition performance measured by Accuracy rate. This result is in agreement with previous studies demonstrating that emotional facial expressions recognition starts early in infancy and continues through childhood, adolescence, and adulthood (Herba & Phillips, 2004). Kolb et al., (1992) described a trend in facial expression recognition from childhood to adolescence which is coherent with a linear increment. Indeed, an improvement in the perception of facial expressions was shown between the ages of 6 and 8 years, whereas little changes were evidenced until about 13 years, followed by a second improvement to adult performance at about 14 years (Kolb et al., 1992).

On the other hand, the absence of linear relation between age and Accuracy rate among street-boys demonstrate that prolonged trauma exposure prevents the natural age-related improvement in emotion recognition, but does not induce a progressive impairment in the overall victims' performance in facial expressions recognition. This results is quite conflicting with that reported by Sloutsky (1997) who found that performance to emotion identification task was negatively related to time spent in the orphanage in 6- and 7-year-old children (Sloutsky, 1997). The different victims' age-range considered in the two studies could justify that difference. Furthermore, the analysis of Anger False Alarms rate, confirmed for the first time, that the recognition bias for angry facial expressions caused by an adjustment of victims' attentive and perceptive mechanisms (Pollak, 2008), is not influenced by prolonged trauma exposure. Coherently, bias in angry facial expressions recognition has been evidenced among children and adolescents and also following a single traumatic events (Ardizzi et al., 2013; Fries & Pollak, 2004; Pollak et al., 2000, 2009; Pollak & Kistler, 2002; Pollak & Sinha, 2002; Scrimin et al., 2009).

Taken together the present results demonstrate that the childhood exposure to high levels of maltreatment and neglect prevents the natural development of the recognition of facial expressions of emotions, inducing a specific bias for angry facial expressions, which is not influenced by the prolonged nature of trauma. Probably, trauma exposure at specific developmental stage relevant for the recognition of facial expressions of emotions justifies these effects.

The comparison between street-boys' and controls' facial EMG (i.e., Corrugator EMG activity, Zygomaticus EMG activity) and vagal regulation recorded in resting periods (i.e., Baseline RSA value, Recovery RSA value) demonstrated a significant difference only in Corrugator EMG activity, as expected. This finding suggests that in a wide age-range sample the exposure to prolonged experiences of maltreatment and neglect most influences congruent Facial Mimicry of negative facial expressions, which is involved in empathy, emotional reciprocity and recognition (V. Gallese, 2013; Niedenthal, 2007; Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005). Recently, it has been demonstrated among healthy participants that the suppression of Facial Mimicry in response to both positive and negative facial expressions induces impairments in facial affect sensitivity (Schneider, Hempel, & Lynch, 2013). Protracted exposure to hostile, aversive and aggressive environments during childhood primarily affects both explicit recognition and implicit empathic resonance to others' negative facial expressions.

This conclusion is further extended by curve estimation analyses investigating the impact trajectories of trauma exposure on Facial EMG activities recorded in response to different facial expressions of emotions. No significant relations between age and facial EMG activities were found among controls. This results is coherent with previous studies suggesting an absence of developmental trajectories in Facial Mimicry responses from childhood to adolescence. Despite longitudinal studies regarding typical Facial Mimicry development across different ages are still lacking, studies about Facial Mimicry in different age samples, demonstrated the presence of a congruent Facial Mimicry response to positive and negative facial expressions among school-aged children similarly to what happens in adolescent and adult populations (Ardizzi et al., 2014; Dimberg & Thunberg, 1998). For example, two studies compared facial EMG reactions in healthy controls (average age 10 years) with boys with conduct problems (De Wied et al., 2009; de Wied et al., 2006). Two other studies assessed facial mimicry of typically developing children compared to children with autism spectrum disorders (average age 9–10 years) (Beall et al., 2008; Oberman et al., 2009). More recently, a study assessed the feasibility of using facial EMG as a method to study facial mimicry responses in young children aged 6–7 years to emotional facial expressions of other children (Deschamps, Schutte, Kenemans, Matthys, & Schutter, 2012). Results showed that the presentation of angry faces was associated with corrugator activation and zygomaticus relaxation, happy faces with an increase in zygomaticus and a decrease in corrugator activation, fearful faces with frontalis activation, and sad faces with a combination of corrugator and frontalis activation. Taken together, these studies show that specific mimicry to angry faces (an increase in activity in the Corrugator muscle) and happy faces (an increase in the Zygomaticus major muscle) is developed in healthy children at least starting from 6 years old. Considering these conclusions, differences in Facial Mimicry responses to negative facial expressions between healthy population of children and adolescent are not to be expected, as the present results confirmed. On the contrary, our analyses evidenced that trauma exposure induced a progressive decrease of congruent Facial Mimicry to negative facial expressions (Corrugator response to angry, fear and sadness facial expressions) and an increase of incongruent facial mimicry to angry facial expression (Zygomaticus response to angry facial expression). These results extend previous findings demonstrating that the significant difference in Corrugator EMG activity evidenced between groups was caused by a progressive reduction of congruent Facial Mimicry to negative expressions of emotions proportional to trauma exposure. The longer trauma exposure, the higher Corrugator EMG suppression to negative facial expressions of emotions. The influence of protracted trauma on physiological mechanisms underlying implicit empathic understanding of others' emotions is progressive and related to trauma exposure. Despite a relation between age and Corrugator EMG activities was evidenced for all the negative facial expressions of emotions employed (i.e., anger, fear and sadness), it was not always linear. In the case of sadness facial expressions, indeed, a logarithmic curve better fits data distribution than a linear one. These results suggest a charging impact trajectory, in which the early years of trauma exposure have greater impact on Corrugator EMG activity reduction in response to sadness facial expressions than the later ones. It is possible that living in a hostile, aggressive and high competitive environment like the one experienced by street-boys, requires an immediate reduction of empathic resonance to others' sadness emotion. Further longitudinal studies, investigating victims' empathic responses to others' sadness facial expressions by means of different dependent measures (e.g., EEG, fMRI or RTs) are needed to confirm this suggestion.

Whereas the described results for Corrugator EMG activities are coherent with preliminary expectations, Zygomaticus response are rather surprising. To our knowledge only two studies reported an increase in incongruent Zygomaticus response to angry facial expressions (E. W. Carr, Winkielman, & Oveis, 2014; McIntosh et al., 2006). McIntosh et al., (2006) described, among adolescents suffered from Autism Spectrum Disorders (ASD), a prevalence of incongruous Facial Mimicry responses (defined as participants' Corrugator activity to joy expressions and participants' Zygomaticus activity to angry expressions) to both angry and joy facial expressions. Moreover, ASD participants showed lower congruent Facial Mimicry responses (defined as participants' Corrugator activity to angry expressions and participants' Zygomaticus activity to joy expressions) than healthy participants. These results demonstrated a consistent alteration of the normal pattern of Facial Mimicry responses as a consequence of a developmental disorder characterized by impairments in social and emotional abilities, deficits in communication and language skills. The second study (E. W. Carr et al., 2014) examined in an healthy adult sample how social power fundamentally changes spontaneous Facial Mimicry of emotional expressions. Participants induced into a high-power (HP), low-power (LP), or neutral state watched dynamic joy and angry expressions from HP and LP targets while facial EMG activities were recorded. Results evidenced that LP participants activated Zygomaticus muscle in response to all targets, regardless of their facial expressions of emotions. Carr et al., (2014) demonstrated that spontaneous Facial Mimicry adapts to contextual cues, social hierarchy in that case. Our results demonstrate that also hostile environmental conditions can influence automatic Facial Mimicry, not only by reducing its congruent activation to negative facial expressions, but also by eliciting an incongruent response to aversive and threatening facial expressions of emotion, like anger. It is possible that higher Zygomaticus activity to angry facial expressions may act as a defensive strategy to others' hostile behavior.

Curve estimation analyses conducted on RSA responses to facial expressions of emotions revealed unexpected results. Our attended results were hypothesized basing on previous researches conducted by our research group involving street-children and street-boys, as well as, age-matched controls in which vagal regulation in response to both positive and negative facial expression of emotions were investigated (see Chapters II and IV). Indeed, no other study, investigated this point. Bearing in mind the vagal regulation observed in these two independent studies (see Chapters II and IV), we expected to find significant relation between age and RSA response to all facial expressions of emotions among street-boys and a significant relation between age and RSA response to angry facial expressions among controls.

Unexpectedly, curve estimation analyses demonstrated significant relations between age and street-boys' RSA response to anger and sadness facial expressions, whereas no significant relations were estimated for control participants. These results suggest that prolonged trauma exposure, and not natural development progressively influence vagal regulation to others' facial expressions of emotions. Trauma exposure induces linear and non-linear RSA response decrement to anger and sadness facial expressions, presumably because of higher sympathetic responses. These results are in agreement with previous studies showing vagal withdrawal and sympathetic activation when maltreated and neglected young individuals were exposed to social conditions (Cook et al., 2012; Fries et al., 2008; Oosterman et al., 2010; Skowron et al., 2014). Our results extend these previous findings, by demonstrating a similar trend also in response to angry and sadness facial expressions and two different impact trajectories of prolonged trauma. RSA response to angry facial expressions linearly decrease with longer trauma exposure, otherwise, RSA responses to sadness facial expressions show quadratic trajectories. From 5 to 11 years of age, RSA responses to sadness facial expressions decrease with trauma exposure. An inversion was shown at the age of 12. Hence, from 12 to 17 years of age street-boys' RSA response to sadness facial expressions increase with trauma exposure. It seem that at a later stage of trauma exposure vagal regulation increases in response to others' sadness facial expression. At the present state of art it is difficult to interpret this result. Further research is needed to better clarify the autonomic regulation in response to facial expressions of sadness.

Finally, curve estimation analyses conducted on controls' Baseline and Recovery RSA values did not show significant relations with age. This is in agreement with previous studies demonstrating that developmental changes in RSA increase over infancy but remain relatively stable through childhood and adolescence (Alkon et al., 2006; Bar-Haim et al., 2000; Bornstein & Suess, 2000; Calkins & Keane, 2004; El-Sheikh, 2005; Hinnant et al., 2011; P J Marshall & Stevenson-Hinde, 1998; Michelle A Patriquin et al., 2014; Salomon, 2005). On the contrary a significative relation between age and Baseline RSA was found among street-boys. Trauma exposure influenced street-boys' Baseline RSA, but not Recovery RSA, following quadratic trajectory. From 5 to 11 years of age, vagal modulation increase with trauma exposure. An inversion was shown at the age of 12. Hence, from 12 to 17 years of age street-boys' vagal modulation decrease with trauma exposure. Previous studies evidenced that exposure to hostile environmental conditions influencea autonomic regulation at rest condition (Ardizzi et al., 2013; Miskovic et al., 2009), but until today, no study investigated the impact trajectories of prolonged trauma exposure. The present results suggest the presence of an initial phase of compensatory vagal recruitment, followed, for longer traumatic conditions, by consistent vagal withdrawal presumably in favor of sympathetic regulation. This non-linear impact trajectory is in agreement with functional and anatomical alteration in brain regions crucial for monitoring of behavioral outcomes, like OrbitoFrontal Cortex (OFC). Early dysfunction of the OFC may not become apparent until adolescence or early adulthood, when this brain region becomes fully functional (Hanson et al., 2010).

Limits

As already mentioned (see Chapter II - paragraph II.a and paragraph II.d, Limits subsection), empirical designs focusing on narrow samples exposed to single trauma type, although informative about the impact of a single traumatic experience on measured dependent variables, resulted at the same time, artificial, non-ecological and have many significant limitations including the lack of random assignment. Furthermore, many variables (e.g., victims' age, gender, socio-economics states, duration of trauma exposure, oppressor identity) could influence trauma effects and so require a rigorous experimental control, almost always not achieved. In this perspective, it has been suggested that the empirical attempts to investigate the effects of one traumatic event on a narrow homogeneous population (e.g., intra-familiar sexual abuse among mid-classes females), even if potentially informative on the specific influence of that kind of trauma, could be the cause for contradictory results obtained in different studies (Hanson et al., 2014). On the contrary, the involvement of a wide and uneven sample of participants exposed to different forms of trauma results an alternative and efficient strategy because it allows to minimize the impact of varied and frequently unmeasured characteristics of specific stressful experiences maintaining, at the same time, an ecological sample representation. Obviously, the involvement of this latter kind of sample prevents the evaluation of the specific impact of a single traumatic experience. In the present study we preferred to sacrifice the investigation of specific trauma experience effects in favor of an ecological examination of trauma exposure effects and ensuring a more rigorous control on the possible interfering variables. Hence, street-boys lived in pervasive and perennial hostile conditions: they experienced physical violence from peers and adults, were abandoned by their family, they suffered high levels of neglect, and at the moment of the experiment, they were serving a prison sentence. For these reasons street-boys could not be included in a single trauma category (e.g. physical abuse, neglect, maltreatment) and, consequently, the present conclusions could not evaluate the specific impact of each traumatic experience.

Questionnaires evaluating cognitive and psychological aspects were not administered due to the lack of validated scales on this kind of sample.

To avoid gender influence only males were included in the experiments, so our conclusions can not be extended to females.

Finally, in the present study age was used as an indirect, but effective, index of trauma exposure in a wide age-range sample. Naturally, when considering the recognition of facial expressions of emotions, Facial Mimicry and vagal regulation, participants' age resulted also an index of the natural development. Although, our results disambiguate between trauma exposure impact and normal development influences founding different impact trajectories between the two experimental groups, further research could clarify this issue by recruiting participants of the same age exposed to different trauma duration.

Conclusions

Prolonged exposure to high levels of maltreatment and neglect induces a progressive decrement of congruous Facial Mimicry in response to negative facial expressions of emotions, along with, a linear increment of incongruous Facial Mimicry to angry facial expressions. Moreover, trauma exposure induces a linear reduction of RSA response to angry facial expression, whereas, a quadratic impact trajectory was estimated in vagal regulation during resting condition. Taken together these results allow for the first time to better clarify how and to what extent prolonged conditions of maltreatment and neglect influence the physiological mechanisms involved in empathic understanding of others' emotion and self-regulation, frequently altered following these negative experiences in childhood.

The impact trajectories study allows to better understand the natural patterns of resilience, improvement, deterioration, and chronicity, providing clues for new coherent rehabilitative projects. Further studies are required to investigate whether, following therapeutic interventions, different impact trajectories could be expected.

The present dissertation focuses on the influence of childhood experiences on social development. Development, and particularly social development, is nested within both biological and social contexts (Silk et al., 2014). Our approach aims to chart how the dynamic interplay of biological, social, and emotional influences shapes developmental trajectories.

We started from the consideration that facial expressions of emotions are important social cues by which internal states (i.e., emotions, feelings, intentions and dispositions) are communicated and shared by humans. Consequently, we argued that the efficient recognition of facial expressions of emotions represents a crucial social skill, on which children's subsequent behavioral responses will depend.

In this context, we referred to a solid empirical literature demonstrating that beside the explicit recognition of facial expressions of emotions improving with age (Herba & Phillips, 2004), also an automatic, unconscious and rapid response to others' facial expressions of emotions can be described. The implicit processing of others' facial expressions of emotions is called Facial Mimicry and defined as the observer's congruent facial muscular activation in response to other people facial expressions of emotions (Dimberg et al., 2000; Dimberg & Thunberg, 1998; Dimberg, 1988). Facial Mimicry assumes a special importance for the present dissertation because it reflects a basic aspect of intersubjectivity which allows a direct and immediate understanding of others' emotion by means of the "internal body-based simulation" of the perceived facial expressions of emotions (V. Gallese, 2013; Vittorio Gallese, 2003; Iacoboni, 2009; Niedenthal, 2007). Including Facial Mimicry within the broader Embodied Simulation perspective (V. Gallese, 2013; Vittorio Gallese & Sinigaglia, 2011; Vittorio Gallese, 2003, 2007) which concerns also other domains of intersubjectivity (e.g., action, sensation), it has been suggested that Facial Mimicry facilitates empathy, emotional reciprocity and recognition, and thus characterizes interpersonal relationships in a meaningful, affective fashion (Iacoboni, 2009). Considering the efficient processing of other people's facial expressions of emotions as a fundamental social skill driving also the subsequent behavioral responses, we described how the Autonomic Nervous System, and especially the vagal regulation responses, could represent a valid measure of individuals' ability to self-regulate in social contexts (S W Porges, 2003a; Stephen W Porges, Doussard-Roosevelt, & Maiti, 2011). Hence, the vagal activity, which can be indirectly estimated by means RSA recording (Berntson et al., 1993), resulted particularly implicated in the autonomic regulation of numerous social behaviors and it has been proposed to be a consistent measure of humans' ability to adapt autonomic responses to environmental social stimuli and to establish a physiological state suitable for social relations (S W Porges, 2003a, 2003b, 2007; Stephen W Porges et al., 2011).

The study of these processes allows to examine physiological, implicit, automatic and unconscious mechanisms which, along with others, constitute basic building-blocks of humans' social interaction.

A second consideration guided the present dissertation. Empirical and clinical evidence shows that prolonged exposure to multiple and repeated forms of trauma during childhood leads to outcomes that are not simply more severe than the sequelae of single incident trauma, but are also qualitatively different (Cloitre et al., 2009, 2011, 2013, 2014; Ginzburg & Solomon, 2011). Interestingly, these specific outcomes are related to affective dysregulation, negative self-concept, and interpersonal problems. Among others, poor emotions understanding, reduced empathic resonance, as well as incoherent behavioral reactions to external social stimuli have been described (Cloitre et al., 2013).

Bearing in mind these two opening considerations, the study of the influence of childhood protracted conditions of maltreatment and neglect on the explicit recognition of facial expressions of emotions, along with, Facial Mimicry and vagal regulation in response to facial expressions of emotions - as physiological measures of humans' empathic resonance and self-regulation in social context respectively - appeared particularly interesting. In the present dissertation we examined, in four successive experiments, Sierra

Leonean street-children and street-boys exposed to high and protracted conditions of maltreatment and neglect.

In the first experiment, described in Chapter II, a sample of Sierra Leonean street-boys, all males, was submitted to a forced-choice facial expressions recognition task, as well as, to a facial expressions perceptual task during which facial EMG activities and RSA responses were recorded. Results demonstrated at the explicit level the well-known bias for angry facial expressions (Gibb, Schofield, & Coles, 2009; Pollak & Kistler, 2002; Pollak et al., 2000; Pollak & Sinha, 2002; Scrimin et al., 2009), considered a measure of perceptive/attentive mechanisms of attunement to external hostile environment (Pollak, 2008). At the implicit and physiological levels, when compared to age-matched controls, street-boys' Facial Mimicry and vagal regulation responses manifested severe impairments. Congruent electromyographic responses (i.e., Corrugator activity for negative facial expressions and Zygomaticus activity for positive expressions) of street-boys resulted significantly weaker than those of controls. Furthermore, the Corrugator activity of street-boys did not show the habitual modulation for positive and negative stimuli (Dimberg, 1990; Fridlund & Cacioppo, 1986; Lang et al., 1993). These alterations of automatic and unconscious reactions to facial expressions demonstrated that the exposure to high levels of maltreatment and neglect influences the basic processes supporting empathy, emotional reciprocity and emotion recognition (Iacoboni, 2009; Niedenthal, 2007; Oberman et al., 2007). At the autonomic level street-boys showed significant lower RSA value recorded at rest condition after experiment execution, furthermore they showed a significant correlation between Mean Baseline and RSA suppression for non-threatening facial expressions (i.e., fear, sadness and joy), suggesting that in response to others' non-threatening facial expressions of emotions they recruited the autonomic subsystem promoting defensive behaviors (fight/flight or immobilization), instead of the one enabling social communication and disposition. Taken together these results confirmed clinical observations regarding empathic and self-regulation impairments following early exposure to traumatic experiences. Our results demonstrated in an adolescent population, how these alterations are deeply rooted at the physiological level.

In a second experiment, reported in Chapter III, a sample of Sierra Leonean street-children performed the same forced-choice facial expressions recognition task. To replicate the same paradigm employed with street-boys on a younger population of street-children was relevant because: First, it is widely known that the explicit recognition of facial expressions of emotions gradually improves with age (Boyatzis et al., 1993; Herba & Phillips, 2004; Martínez-Castilla et al., 2014; Odom & Lemond, 1972; Philippot & Feldman, 1990); Second, because when investigating the impact of protracted traumatic experiences, different victims' ages correspond to different levels of trauma exposure. Results, again, confirmed street-children's recognition bias for angry facial expression of emotions. Moreover, it was demonstrated that individual cognitive and educational levels and naming skills did not influence participants' tendency in the use of angry label. Moreover, a similar tendency to use anger label, tough significantly minor than in street-children, was evidenced also among control children and attributed to the natural development of the explicit recognition of facial expressions of emotions (Herba & Phillips, 2004). Hence, at an initial developmental stage, in response to an unclear negative facial expression children generally tend to attribute the most salient and better recognized negative emotion, that is anger. These data suggest that exposure to maltreating and neglectful environment during childhood alters the normal development of the recognition of facial expressions of emotions, worsening children's bias towards the identification of specific negative facial expressions.

The demonstrated presence of a bias for angry facial expressions recognition among both street-boys (see Chapter II) and street-children (see Chapter III) shows that explicit bias in the recognition of angry facial expressions is present regardless of the degree of trauma exposure. This conclusion triggered our interest in evaluating Facial Mimicry and vagal regulation responses to facial expressions of emotions in a sample of children exposed to maltreatment and neglect. To this aim, in a third experiment, here described in Chapter

IV, the previously employed perceptual task of facial expressions of emotions was replicated on a sample of street-children. Results demonstrated that street-children did not differ from age-matched controls for the amplitude of their recorded physiological responses (i.e., facial EMG and RSA at rest conditions). However, they differed for the modulation of these physiological responses to social stimuli. Hence, street-children, but not controls, showed an absence of modulation of Corrugator facial mimicry in response to positive and negative facial expressions of emotions. This positive/negative modulation is completely automatic and involuntary (Dimberg et al., 2002) and it has been demonstrated to predict experienced emotional valence in response to dynamic facial expressions (Neta et al., 2010; Sato et al., 2013). This result demonstrates that before an alteration of the overall empathic resonance by means of a general Facial Mimicry suppression, it is the ability to implicitly differentiate between positive and negative emotional valence that is damaged first. Moreover, street-children, manifested an earlier development of the functional synchronization between vagal regulation and threatening stimuli in external environment with respect to controls. Indeed, street-children showed a significant correlation between Baseline RSA and RSA suppression values in response to threatening facial expressions, whereas, control children did not. These results demonstrate the existence of an early, although differentiated, influence of childhood exposure to high levels of maltreatment and neglect on Facial Mimicry and vagal regulation during the perception of facial expressions of emotions.

In these first three experiments we could reveal both in children and adolescents the significant influence of childhood maltreatment and neglect on explicit recognition of facial expressions of emotions, on Facial Mimicry and on vagal regulation. This suggests a possible and differentiated additive effect of trauma exposure. This last point was specifically addressed in the last experiment described in Chapter V. In order to evaluate the impact trajectories of prolonged experience of maltreatment and neglect on the explicit recognition of facial expressions of emotion, Facial Mimicry and vagal regulation, two groups of Sierra Leonean minors (age range: 5-17 years) were recruited. One was composed by street-boys and one by family-reared age-matched controls. They performed the forced-choice facial expressions recognition task, as well as, the facial expressions perceptual task during which facial EMG activations and RSA responses were recorded. Because of street-boys' demographic characteristics (all participants were permanently street-boys from the age of 5), age was considered an indirect, but efficient, index of trauma exposure. The aim of this latter study is particularly important because the investigation of impact trajectories of prolonged traumatic experiences allows to gain a better picture of the natural patterns of resistance, improvement, deterioration, and chronicity, hence providing clues for coherent rehabilitative interventions.

The obtained results demonstrated that prolonged conditions of maltreatment and neglect progressively influence the physiological mechanisms involved in empathic understanding of others' emotion and self-regulation, but not the explicit recognition of facial expressions of emotions. In fact, age predicts controls' accuracy rate in the forced-choice facial expressions recognition task, whereas no significant relation was found for street-boys between age and accuracy rate. Moreover, age did not predict participants' tendency to erroneously over-attribute anger label. These results demonstrated that increasing levels of maltreatment and neglect prevent the natural development of the recognition of facial expressions of emotions, inducing a specific bias for angry facial expressions, which is not influenced by the prolonged nature of trauma.

Considering the physiological responses to facial expressions of emotions, results showed that street-boys' age predicted the decrease of street-boys' Corrugator EMG activities recorded in response to all negative facial expressions of emotions (i.e., anger, fear and sadness). Opposite, street-boys' age predicted the increment of street-boys' Zygomaticus EMG activities to angry facial expression of emotions. Moreover, a significant relation was found between street-boys' age and the reduction of street-boys' RSA responses to both angry and sadness facial expressions. No relation between controls' age and their physiological responses to facial expressions of emotions resulted significant. These results demonstrated that prolonged exposure to high levels of maltreatment and neglect induces a progressive decrement of congruous Facial Mimicry in response to negative facial expressions of emotions, along with a linear increment of incongruous Facial Mimicry to angry facial expressions. Furthermore, trauma exposure induces a progressive reduction of RSA response to angry and sadness facial expressions.

Examining the relation between RSA value recorded at rest condition and participants' age, a significant quadratic relation between the two was found only among street-boys. From 5 to 11 years of age, street-boys' vagal modulation increases with trauma exposure, whereas an inversion occurs at the age of 12. This pattern of results describes a specific impact trajectory of trauma exposure which causes an initial phase of compensatory vagal recruitment, followed, for longer traumatic conditions, by consistent vagal withdrawal. Presumably longer trauma exposure prevents an efficient vagal compensation in favor of a sympathetic sub-system recruitment. This impact trajectory may represent one of the mechanisms by which longer traumatic exposure are associated with greater behavioral disturbances.

Taken together these results demonstrate that protracted trauma exposure induces specific alterations in Facial Mimicry and vagal regulation to others' facial expressions of emotions, which follow different impact trajectories. Longer trauma exposure seem to accentuate an incoherent Facial Mimicry and a lower vagal regulation, particularly in response to angry facial expression of emotions. The presence of a compensatory vagal recruitment during the first years of trauma exposure gives important suggestions about temporal windows in which rehabilitative interventions can likely contrast the occurrence of chronic outcomes.

In conclusion, the present dissertation provides new and further evidence of the influence of childhood experiences on social development by confirming the huge impact of prolonged experiences of maltreatment and neglect on the understanding of emotions, empathic resonance, and self-regulation in social contexts. Moreover, the studies here described investigated for the first time, three different but intertwined aspects of social behavior (i.e., explicit recognition of facial expressions of emotions, Facial Mimicry and vagal regulation), providing new relevant information on how they are differently influenced by prolonged traumatic experiences both at different ages and from a longitudinal point of view. If as Aristotle wrote "*Man is by nature a social animal*" and as recent neuroscientific evidence suggested the human mind is ontogenetically interpersonal and wired to be social (Castiello et al., 2010), it is clear that early traumatic experiences negatively influence physiological mechanisms supporting our social nature.

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