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**STREET CHILDREN AND EMOTION RECOGNITION:
HOW TRAUMATIC EXPERIENCES AFFECT FACIAL
MIMICRY AMPLITUDE AND LATENCY**

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Introduction

Infancy and childhood are recognized as critical life periods characterized by substantial changes in brain structure and functionality which entail, among others, consistent social and emotional developments.

Before the acquisition of language, infants can express their needs and feelings only through facial expressions of emotions. Hence, the early communications and interactions with others are principally mediated by these facial configurations, which are fundamental to develop social relations and empathic comprehension.

Considering the prolonged biological immaturity, which characterizes human development, the environmental influences (e.g., children's social, emotional and familiar background) critically affect children's development trajectories.

Predominant factors that influence the human development are attachment, socio-economic context, family network, educational and schooling patterns, but also genetic and biological factors.

In this thesis we will investigate how the explicit facial expressions of emotions recognition and the implicit physiological processes involved in empathic resonance and behavioral regulation during social interaction (i.e., facial mimicry and vagal regulation) are influenced by early childhood adverse experiences.

Specifically we will focus on prolonged conditions of maltreatment and neglect experienced by street-children growing-up in difficult conditions without significant adult figures of reference.

Emotions and early social interactions

Emotions are complex and multi-componential processes with a specific adaptive function. They are composed by different factors such as: cognitive evaluation of the stimulus, emotional experience, physiological activation, impulse to action, expressive reaction and overt behavior (Plutchik, 1983). Their adaptive function refers to their twofold communicative nature. From one hand, emotions are intra-subjective: they alert the individual about own body's needs and desires, leading to a functional and prompt psychophysiological adjustment. On the other hand, emotions are inter-subjective: they communicate to other people relevant information about individual internal state and external contingent environment (Lewis & Michalson, 1983).

“Basic emotions” (i.e., joy, fear, anger, sadness, disgust) are considered innate (Anolli & Ciceri, 1992) and derived from biological evolutionary processes finalized to adaptation (Izard, 1991). They are associated to distinctive and specific neural substrates (Izard, 1991) linked to an exact emotional experience that could reach individual awareness (Izard, 1991).

Furthermore, each basic emotion is well-characterized by a determined facial expression (Anolli & Ciceri, 1992), which is universally recognized independently from the culture one belongs to (Ekman, 1984). Recently, controversies raised regarding the innate nature of basic emotions (Camaioni et al., 2002), because, even if it is demonstrated that newborns show expressions of basic emotions from the first days of life (Izard, 1991), the distinctiveness of each one and their specific facial indices are not always recognized (Camaioni et al., 2002).

Basic emotions and their facial expressions acquire particular relevance for the topic here discussed because before the acquisition of language, they are the most communicative vehicle of information about children's and others' feelings and intentions.

During the first 2 months of life newborns' emotional expressions are controlled by biological processes, genetically determined, and related to survival. Typical emotional phenomena in that period of life are startle, distress, interest, pleasure and displeasure; called "emotional reaction". From 2 months to 1 year infants start to communicate their needs and desires. Furthermore, social behaviors like fear of strangers and social smile, appear together with the first facial expressions of emotions (i.e., surprise, joy, sadness, anger and fear) (Anolli, 1995). It is at this developmental stage that emotional expressions appear.

After the first year of age, infants develop social emotions like timidity, contempt, guilt and shame which presuppose a representation of the Self, the others and of the world (Anolli, 1995)

About the emotional recognition, in the first 2 months of life, infants are able to understand the expressions of basic emotions through the analysis of the eyes and mouth that turn out to be very salient stimuli (Haviland et al., 1987).

At 5-6 months infants recognize all configurations of the expressive faces, in particular those of the parents (Haviland et al., 1987).

Focusing on the neural substrate of this social ability, it is important to highlight that infants' mechanisms used to process faces are activated by a wider range of stimuli. During development, the neuronal populations assigned to human faces elaboration become more tuned and specialized (Leppänen & Nelson, 2009). Because of poor visual

acuity in order to discriminate different expressions, newborn focus greater attention to the internal parts of the face, in particular to eyes and mouth. Only around 5-7 months of age they start to use a greater number of cues to detect and discriminate between different emotional facial expressions (Leppänen & Nelson, 2009).

It is demonstrated that the main components of the adult emotion-processing network, which are the amygdala and the orbitofrontal cortex (Leppänen & Nelson, 2009), develop early in childhood (Leppänen & Nelson, 2009). The amygdala responds to coarse and low frequency facial stimuli. It is involved both in the early elaboration of facial stimuli, and in later information processing through feedback projections to face-sensitive areas, like the fusiform gyrus and the superior temporal sulcus (STS) (Leppänen & Nelson, 2009). Furthermore, amygdala plays also an important role in associating stimuli to their emotional value (Leppänen & Nelson, 2009). It is demonstrated that this subcortical region, is already active at birth, enabling newborns to orient their attention toward faces, and enhancing brain activity in response to faces in cortical areas (e.g. orbitofrontal cortex) (Leppänen & Nelson, 2009). The orbitofrontal cortex is involved in emotion recognition through the analysis of facial expressions and the top-down modulation of perceptual processes (Leppänen & Nelson, 2009). This cerebral area contributes to the definition of stimuli valence (Leppänen & Nelson, 2009). The orbitofrontal cortex has reciprocal connections with the amygdala and face-sensitive cortical areas (i.e., infero-temporal regions, STS) and receives information from the low spatial frequency magnocellular neurons (Leppänen & Nelson, 2009).

Studies measured the activity of orbitofrontal cortex in response to positive or negative facial expressions using fMRI and PET (O'Doherty, J. et al., 2003; Blair, R. J. R. et al.,

1999). An enhanced activity in this area is observed when participants understand the associations between object and emotion from stimuli that display facial expressions matched with novel objects. This result supports the putative role of orbitofrontal cortex in representing the negative or positive enhancement value of stimuli (Rolls, E. T, 2007; Hooker, C. I. et al., 2008).

Individual differences about the amplitude of activation and sensitivity to certain emotional signals can be described (Leppänen & Nelson, 2009). For example, individuals with high anxiety traits showed more difficulties in disengaging attention from fearful facial stimuli. Furthermore, they showed a stronger amygdala response to fearful and anger facial expressions of emotions and a less habituation of amygdala activation to repeated facial expression stimuli. This leads to less efficient emotional regulation due to lower amygdala connections with the prefrontal cortex (e.g., anterior cingulate cortex) (Leppänen & Nelson, 2009).

At the end of the first year of age, children are able to regulate their social interactions according to salient social stimuli such as caregiver's facial expressions of emotions. An exemplification of this social ability, is the social reference phenomenon by which children are able to guide their own behaviors according to others' emotions (Sorce et al., 1985).

Beside the social reference phenomenon, children precociously show emotional resonance processes, through which they are able to implicitly understand and respond to other people's emotions (Camaioni et al., 2002). For example, early in life it appears the "emotional contagion" phenomenon, which consists of an unconscious synchronization of children's feelings and emotions with the feelings and emotions expressed by those around them. This tendency for two individuals to emotionally

converge could be observed through modifications of expressions, vocalizations, postures and movements. It is important to note that emotional contagion is frequently observed also among adults, but in infancy this automatic phenomenon still remain undifferentiated between different emotions (Eisemberg, 1986).

Another early link between children's and others' feelings and emotions is the "Emotional containment" phenomenon, firstly introduced by Bion (1962). The infant projects the unmanageable feelings into the primary caregiver who, in turn, reflects them back to the infant. Thanks to this dyadic exchange, infant's feelings become more tolerable and controllable. Emotional containment is a continuous process which includes the functional perceiving and the control of child's discomforts, as well as, the effective response to them. Emotional containment, by being the first functional experience of containment (Bion, 1962) has a strong parallel with attachment processes (Bion, 1962). According to Douglas, an effective containment could be described as follows: "Containment is thought to occur when one person receives and understands the emotional communication of another without being overwhelmed by it, processes it and then communicates understanding and recognition back to the other person. This process can restore the capacity to think in the other person" (Douglas, 2007, p.33). Early experiences of containment enable the development of children's abilities to manage social experiences and emotions. When the early emotional containment is inadequate or viciously interrupted, cognitive and emotional development are affected. Feelings become uncontainable and emotions unmanageable, leading to social and behavioral disturbances affecting the entire lifespan (Bion, 1962).

These briefly described phenomena occurring during childhood demonstrate that children early learn to adjust their own behaviors according to what they feel and to

what they perceive in other people (Eisenberg, 1986). Another important notion that illustrates the development of emotional processes in early stage of life is the Trevarthen's concept of "intersubjectivity"(Trevarthen, 1979). Intersubjectivity is defined as a communicative driven attitude of individuals, through which they adapt their own behaviors to the subjectivity of others(Trevarthen,1979). During face-to-face communications, infants synchronize their facial, vocal and gestural expressions to the expressions of their mothers. In the first two months of life, the mother-child dyad relationship is governed by a primary intersubjectivity process characterized by newborns' imitation, proto-conversations and empathic interactions whose purpose is to establish positive emotional bonds with the two (Trevarthen, 1979).

All these first emotional exchanges with the caregiver are fundamental for the development of functional and effective abilities in emotion understanding and communication. These consideration are especially described in studies investigating the children's attachment.

Attachment and emotions

Camaioni considers children's emotions in relation with the adults, affirming that children's expression of emotions acquires a relevant meaning within the relationship between the child and the adults (Camaioni et al., 2002). Being emotions fundamental both in social communication and individual regulation of one's own inner experiences, they can be described as social and cognitive mediators (Harris, 1989).

As previously described, caregivers represent the children's emotional support . By means of an adequate response to child's signals, they play a scaffolding function

(Bruner, 1977; Kaye, 1982) and they orient the children's emotional expressions according to the social and cultural rules (Camaioni et al., 2002).

Attachment is a biological, innate and intrinsic predisposition, leading to a need of contact and comfort from the person providing the infants with adequate care enabling survival. It is characterized by behaviors derived by biologically programmed schemes and performed with the aim to maintain caregivers' proximity (Bowlby, 1969). This link, between the newborn and the caregiver, is established in the early months of life but it persists for the whole lifetime. Pioneering research describes the mother as the main caregiver because she is the adult figure who spends most time with the child (Bowlby, 1969). Recently, several studies have shown that attachment bonds with the father or with the family are also possible (De Wolff & Van Ijzendoorn, 1997).

During the first months of life, the quality of the relationship with the caregiver plays a crucial role in the determining the child's secure attachment and leads to the formation of internal working models (IWM) defined as a "mnemonic representations derived from episodic memory and semantics images of self and adults" (Camaioni, 2002, p.232). The presence of IWM demonstrates that the child owns a functional representation of self and others derived by the relation with the outside world (Bowlby, 1969). The development of secure attachment bond leads the infant to entertain a positive image of himself as an individual able to help, understand and respond to others. On the contrary, an insecure bond brings the child to have a negative representation of himself as an individual not able to help or understand others, not worthy of affection, isolated, hostile and distant. The attachment bond quality affects also the ability of the infant to build, in the future, positive peers relationships, to create

a good self-concept, to efficiently solve social problems (Thompson, 2008), to regulate negative emotions, and to develop effective coping strategies (Contreras et al. 2000).

Most importantly for the present dissertation, secure attachment bonds are related to children's empathic abilities (M. Sonnby Borgström, 2002) and to children's physiological responses to others' facial expressions of emotions (M. Sonnby Borgström, 2002).

It has also been demonstrated that the relation between the mother and the child influences the children's emotion regulation and their understanding of others' emotions (F. Waters et al. 2010). A study conducted on child-mother dyads involved in a frustrating test, proves that only the dyads with secure attachment speak about negative feelings. Furthermore, mothers who attributed to his son the proper mood, were considered to promote a secure attachment bond.

Empathy and Facial Mimicry

Empathy is a multidimensional construct difficult to define. Titchener (1909) used the term "empathy" to describe the way in which people are able to immerse themselves objectively in others' experiences in order to understand more deeply how and what they feel. More recently the attempts to define and systematize the human empathic abilities increased with the contribution of different disciplines.

Batson (2009) describes empathy through eight different components:

- learning about others' internal states, affective and cognitive;
- adopting the posture or matching the neural response of another;
- feeling what another feels;
- projecting oneself into another's situation;

- imaging the thoughts and feelings of another;
- speculating what another might think and feel in a different context;
- becoming distressed seeing another's suffering;
- feeling for another person who is suffering.

Preston and de Waal (2002) proposed a model to understand empathy called Perception-Action Model (PAM). The PAM holds that the perception of the others' mood elicits automatically in the observer significant representations of the situation and other's sentiments predicting also observer's automatic and somatic responses. This interpretation has been described as related to the affective state of the other. The PAM consider the empathic responses as based on neural circuits that are activated in the observer in an automatic and unconscious way. From this perspective, the affective components of empathy are defined as immediate and generated by physiological and visceral activations (de Waal, 2008). According to this model, empathy is promoted by behaviors dependent from perception-action mechanisms like motor mimicry, imitation, Simon effect, ideo-motor behaviors and response preparation (Neumann & Westbury, 2011). A more inclusive model of empathy was proposed by Gallese who introduced the notion of 'embodied simulation' (2003 a,b, 2005, 2007), capitalizing on the variety of mirror mechanisms revealed in the human brain after the discovery of mirror neurons in macaque monkeys' brain (Gallese et al. 1996). Such mechanisms are not only confined to emotions, but also encompass actions and sensations.

Facial mimicry is an automatic and unconscious motor phenomenon which illustrates the robust link between empathy and perception-action mechanisms.

Facial mimicry is an index of individuals' tendency to show muscular activations of the same facial muscles involved in the observed facial expression of emotion of others

(Dimberg, 2000). It can be measured by the superficial recording of facial muscles electromyographic (EMG) responses. Similar mimicry processes have also been described in posture and voice tone (Lipps, 1903) which are closely related with empathy and probably with specific neural circuits (e.g. anterior insula, somatosensory cortex, anterior midcingulate cortex, periaqueductal gray, supplementary motor area) (Decety, Michalska, and Akitsuki, 2008; Gallese et al. 2004; Gallese and Sinigaglia 2011; Hatfield et al., 1994; Hoffman, 2002; Meltzoff and Decety, 2003; Preston and de Waal, 2002).

Studies concerning facial EMG demonstrated that the facial muscular activation in response to others' facial expressions of emotions is very fast, under 400 ms (Dimberg and Thunberg, 1998), automatic (Dimberg, Thunberg, and Grunedal, 2002) and occurs also when subjects are unconsciously exposed to facial stimuli (Dimberg, Thunberg, and Elmehed, 2000). These studies demonstrate that mimicry is a quick and spontaneous phenomenon (Dimberg and Thunberg, 1998) and that it is much more informative about the emotion felt when associated with EEG and neuroimaging (Achaïbou, Pourtois, Schwartz, and Vuilleumier, 2008). Furthermore, a recent study demonstrate that Facial EMG responses to static facial expressions of emotions (i.e., joy and anger) are similar to those recorded in response to dynamic stimuli (Fujimura, Sato, and Suzuki, 2010). The facial muscles more involved in the expressions of positive and negative facial expressions of emotions, and so primarily recorded, are the Corrugator Supercilii and Zygomatic muscles (Neumann & Westbury, 2011). The first one is activated especially for facial stimuli that express negative emotions, such as anger, sadness and fear (Dimberg and Thunberg, 1998; Fujimura et al., 2010); whereas the

second one is activated by facial expressions displaying joy or positive emotions (Achaibou et al., 2008; Fijimura et al., 2010).

This pattern of muscular responses reflects a spontaneous modulation related to positive or negative stimuli emotional valence. Specifically, Corrugator activity is related to negative valence, whereas Zygomaticus activity is linked to positive emotional valence (Sato, Fujimura, Kochiyama, & Suzuki, 2013). Moreover, the distinction between positive and negative emotions is completely automatic and involuntary, as demonstrated by the inability to suppress congruent muscular reactions in response to positive or negative stimuli, even when it is required to inhibit it or to voluntarily produce incongruent muscular reactions (Dimberg et al., 2002).

Despite facial mimicry, measured by facial EMG, is a rapid and automatic response, it can be influenced by different factors. A recent study demonstrates, for example, an “ethnic bias” in facial EMG responses. Stronger facial mimicry activations are shown when participants observe facial expressions of emotions performed by people belonging to their “ethnic group” (i.e., African American). On the contrary, weaker facial mimicry activations are shown when participants observe facial expressions of emotions performed by people of different “ethnic group” (i.e. European American) (Brown, Bradley and Lang, 2006). Moreover, only European American participants show stronger electrodermal responses to the view of positive or negative facial expressions of emotions displayed by people coming from their own same ethnic group, compared with the viewing of the same facial expressions performed by a member of a different group. These results, demonstrate the existence of an in-groups empathic bias response (Brown, Bradley and Lang, 2006).

Different muscular activations to facial expressions of emotions are also evidenced according to the observer and the observed age. Recent study demonstrates the existence of an age group membership effect on Facial Mimicry and vagal autonomic regulation. Greater EMG response is observed in teenagers viewing facial expressions of peers; on the contrary higher vagal regulation is shown in adults when exposed to unfamiliar adults' facial expressions (Ardizzi et al. 2013). These results demonstrate not only that facial mimicry is influenced by factors related to the identity of the people involved, but also that different participants' ages correspond to different ways to engage in social interactions.

Achaibou et al. (2008) measured facial EMG and EEG at the same time, while participants observed video clips showing anger and joy facial expressions. As expected, Zygomaticus discloses less activation during videos of anger, whereas the Corrugator showed a reduced response during videos of joy. In addition, a positive correlation was revealed between the amplitude of right visually-evoked P100 potential and Zygomaticus and Corrugator activities in response to the different facial expressions. Conversely, the N170 component negatively correlated with both Zygomaticus and Corrugator activities. These results evidence the existence of specific and differentiated neural substrates supporting facial mimicry responses to angry and joy facial expressions, and furthermore they strengthen the relation between empathy and perception-action neural mechanisms.

Sonnby-Borgström (2002) demonstrated a strong relation between empathy and facial mimicry responses to others' facial expressions in a sample of healthy adult participants. In fact, a strong relation between implicit and automatic physiological responses to facial expressions of emotions (i.e., Facial EMG) and individual traits of

empathy measured by explicit questionnaire (i.e., Questionnaire Measure of Emotional Empathy) is established (Mehrabian and Epstein, 1972; Sonnby-Borgstrom, 2002; Sonnby-Borgstrom, Jonsson and Svensson, 2003). Moreover, the time of exposure to the stimuli influences the relation between these two indices. Being exposed to stimuli for a short time (17-40 msec) reveals a difference between the participants: those most empathetic show more marked congruent Facial EMG response, indicative of mimicry, compared to less empathetic individuals. Additionally, it is observed that less empathetic individuals show an incongruent Facial EMG responses to angry facial expressions. In other words, participants with lower empathic traits show Zygomatic muscle activation during the visualization of angry face, that is the opposite of what expected, being Zygomatic muscle related to the automatic mimicry of joy facial expressions (Sonnby-Bergstrom, 2002). These differences in muscular activation are independent from self-reported feelings evoked by the observed faces. Thanks to this study, it can be deduced that the effect of empathy reduction is more marked when automatic answers to social stimuli eliciting empathy are investigated, with respect to when conscious and voluntary evaluation processes are implicated (Sonnby-Borgström, 2002). Another physiological parameter measured in facial EMG studies is the latency of muscular activation. It is important to verify if some particular conditions can affect the automatic onset time of facial mimicry responses during emotion recognition in social interactions.

A recent study examined if the view of socially relevant facial expressions (i.e. happy or angry) interacts with participants' execution of congruent or incongruent facial expressions (Otte et al., 2011). Results showed a shorter latency of facial mimicry, measured by facial EMG, when participants perceived and then produced congruent

facial expressions (i.e., happy expression seen, happy expression showed), than when they have to produce incongruent facial expressions (i.e., replying to happy expressions with angry expressions) (Otte et al., 2011). The delayed response in incongruous trial suggests that there is a dissociation between automatic and voluntary muscular responses, that affects the Facial EMG latency.

Another study investigated the onset of automatic facial mimicry during the observation of emotional facial expressions in high functioning Autism Spectrum Disorders (ASD) children, compared to healthy controls (Oberman et al., 2009). ASD participants showed delayed spontaneous facial mimicry, compared to controls, despite the amplitude and the selectivity of facial mimicry did not significantly differ between the two groups. Furthermore, ASD children did not show impaired explicit facial recognition of emotions with respect to controls (Oberman et al., 2009). These results suggest that latency can be an important index of functioning of implicit empathic processes, that could be affected by neuro-psychiatric disorders.

All this evidence, allow to consider facial mimicry a reliable index of the empathic understanding of others' emotions.

Autonomic Regulation and Emotions

The response to other people's facial expressions of emotions requires not only requires empathic resonance – for example trough for example facial mimicry responses as previously described - but also an effective behavioral regulation. Respiratory Sinus Arrhythmia (RSA) is a normal cardiac component resulting from the coupling of the cardiovascular and respiratory systems and controlled by the Vagus nerve (Berntson, Cacioppo, & Quigley, 1993). RSA is involved in the autonomic regulation of many

social behaviors and it is considered an indirect index of humans' skills to accommodate their autonomic responses to environmental social stimuli and to set a physiological state appropriate for social relationships (Porges, 2003). RSA is also considered a valid index of individual self-regulation ability and social disposition (Porges, 2003). Accordingly, low RSA is associated with deficits in social stimuli and gestures understanding and with lower appropriate expression and regulation of emotions (Porges, Doussard-Roosevelt, & Maiti, 1994). Furthermore, higher baseline and a greater RSA suppression is considered an indicator of the individual's ability to adapt to environmental requests (Thayer & Lane, 2000). For example, RSA modulation according to interpersonal social distances can be observed during social interactions among healthy participants (Ferri, Ardizzi, Ambrosecchia, & Gallese, 2013).

The environment and the Human Development

Human development, differently from the development of other animal species, is characterized by a prolonged immaturity period during which newborns require a substantial amount of parents' care. This period of prolonged immaturity leads to the development of higher cognitive abilities, but it also extends the huge influence of the environment on human development (Glaser, 2000).

The newborns' brain, in fact, is characterized by a remarkable plasticity, thanks to the large amount of neurons and synapses. Postnatal brain development is characterized by a growth in volume and by an increase of synaptic density (i.e., synaptogenesis), which in turn improves the integrative capacities of the brain and the functional connections between different cerebral areas. The large amount of synapses is subsequently reduced and paralleled by the strengthening of useful synaptic connections and the reduction of

those that turn out to be less useful. This process, called pruning is defined as Activity-dependent (Harry T. Chugani, 1998). Pruning process continues through adolescence (Harry T. Chugani, 1998) and it represents one of the biological mechanisms by means of which the environment plays a crucial role in child development (Harry T. Chugani, 1998).

The environmental influences on the development of neural circuits can be described as belonging to two comprehensive mechanisms: the experience-expectant and the experience-dependent mechanisms (Leppänen & Nelson, 2009).

Experience-expectant mechanism implies the existence of well-determined critical periods during which brain plasticity is especially sensible to specific stimulations. In the case of lower or absent stimulations during the crucial period, the development of skills and abilities could be lost or deficient. Examples of this mechanism are the acquisition of language and social abilities like the recognition of the facial expression of emotions. In fact, around 6-7 months of age children show an attentional bias for fear facial expressions, because this expression becomes particularly salient in life period during which infants start to explore the environment (Leppänen & Nelson, 2009)

Coherently, studies conducted in orphanages, where the caregiver/children ratio is too low to guarantee enough external stimulation, found a general delay in children's neural development. Specifically language and motor disorders as well as faces and emotions recognition deficits, accompanied with neuroendocrine dysregulation, are observed (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

deficits are associated with missing environmental stimuli at a specific critical period of children's development, due to institutionalization (De Bellis, 2005).

The experience-dependent mechanism reflects the neural plasticity in response to environmental stimuli able to influence the growth of new synapses (Glaser, 2000). The early emergence of some components of the emotion-processing network are further modified by individuals' specific experiences (Leppänen & Nelson, 2009). For example, abused children exposed to a large amount of negative facial expressions and physical or verbal aggressions show greater sensitivity and broader perceptual category discrimination for angry facial expressions when compared to non-abused children (Leppänen & Nelson, 2009). This adaptive mechanism demonstrates how the recognition of facial expressions of emotions is influenced by adequate social signals, which guarantee its normal development (Leppänen & Nelson, 2009) .

From this point of view, differences in emotion recognition are closely connected with individuals' experiences occurred during critical life periods.

Street-children

Among negative experiences that can affect children's social and affective development, there are the prolonged experiences of maltreatment and neglect.

Any act that causes physical and mental harm, real or potential, to individuals under 18 years of age is defined abuse, and it can be physical, psychological or sexual (Panzer, 2008).

Similarly, any lack of care that causes physical or mental, real or even potential harm, to a minor is defined neglect and it can be physical, psychological, educational or medical (Panzer, 2008). Abuse or maltreatment experiences can be characterized by a single act

- in a minority of cases - or by repeated acts over time. Generally, this last eventuality is very common and associated to a dysfunctional relationship with the caregivers.

The effects of the exposure during childhood to adverse experiences of abuse and maltreatment depend both on factors related to the negative experience itself, and on factors directly concerning the victim. The first class of influencing factors includes intensity, frequency, severity and the repetition of the aversive event are included. The second class includes the victim's age, gender, temperament and any disability (De Bellis, 2005 ; Glaser, 2000; Panzer, 2008). Furthermore, the victim's socio-economic status, as well as, the prenatal exposure to drug, victim's malnutrition, domestic violence and low educational level can be included as variables that influence, facilitate and enhance the negative effects of adverse experiences occurred during childhood.

Street-children's life condition concerns high levels of both abuse and neglect, probably affecting their development trajectories. The definition of this group of children provided by Inter-NGO Program (UNCHS, 2000) is the following: "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 ". Despite street-children are difficult to quantify, recent UNICEF report (2005) estimated the total number of worldwide street-children to be about 10 millions.

Most of them are males (le Roux & Smith, 1998; Lugalla & Mbwambo, 1999) and start to live on the streets between 9 and 12 years, until the age of 15-16 (Rizzini, 1996). The lack of care to these children is almost total, demonstrating very high levels of neglect. Street-children have to completely provide for their survival and support in terms of food and water, medical care, personal hygiene, and especially of protected and secure

refuge. Without a family or relatives, they lack stable parental, educational, moral and emotional supports (Lugalla & Mbwambo, 1999). This life condition easily leads to high levels of negative experiences such as theft, threats, physical or sexual abuse and involvement in illegal and dangerous activities (UNCHS, 2000). Neglect conditions, abuse and maltreatment episodes are experienced and acted many times by street-children, for a protracted period that sometimes covers their entire childhood and adolescence (UNCHS, 2000). The described life conditions have been demonstrated to be related to substance abuse and problems related to it, and also to a high incidence of psychiatric disorders like depression (Bender, Brown, Thompson, Ferguson, & Langenderfer, 2014). Moreover, numerous studies demonstrate that being exposed to repetitive aversive events facilitates and reinforces the symptoms of Post-Traumatic Stress Disorder (PTSD; Crombach, Bambonyé, & Elbert, 2014; Cloitre et al., 2009; Cloitre et al., 2013; Cloitre et al., 2014). The ICD-11 describes the PTSD as a fear-based disorder characterized by hypervigilance, avoidance, sense of threat, re-experiencing and frequent fear reactions. But what comes closest to the effects of abuse on street children is Complex PTSD, which is associated with chronic and repeated trauma (Briere & Rickards, 2007). In addition to the classic PTSD symptoms, Complex PTSD shows disturbances in self-organization reflected in relationship and emotions regulation difficulties, affective dysregulation, negative self-concept, low emotion understanding and inadequate behavioral responses to social stimuli due to a low empathic resonance (Cloitre et al., 2013).

Specifically, affective disorders include sharp emotionality, self-destructive and reckless behavior, violent reactions with poor ability to self-regulate. Negative self-concept facilitates low self-esteem in the victim, who feels as not being able to deal with

complex situations, accompanied by a sense of guilt for not having been able to provide for others' needs or to prevent their suffering in the past.

The low ability to empathize with others leads to disinterest in relations and low social involvement, because others are not fully understood.

The Social and Affective Neuroscience gives support to what described so far, showing changes in the brain anatomy and activation, particularly in regions involved in self-regulation and in the emotions understanding.

The gray matter volume are measured in children from low-income families (Hanson et al., 2013) and in 8 years-old children with institutionalization past experience (Sheridan, Fox, Zeanah, McLaughlin, and Nelson, 2012). In both studies the brain volume appeared to be reduced when compared to that of children raised in favorable conditions or not-institutionalized.

In a similar vein, a study analyzing autonomic reactivity to an adapted Trier Social Stress Test among non-, early-, and post-institutionalized children revealed that early adopted children displayed a blunted cortisol response to a laboratory stressor whereas post-institutionalized or non-adopted children did not (Gunnar, Frenn, Wewerka, & Ryzin, 2009). These authors propose that moderate levels of early life stress, as opposed to strong levels, might be associated with a blunted cortisol response (Gunnar et al., 2009). Coherently, high levels of cortisol have been found in institutionalized children during the interaction with caregivers (Fries et al., 2008).

An electrophysiological study, comparing institutionalized children and age-matched controls grown in family, highlighted that only the first showed a low frequency (theta) increase in the posterior areas of the scalp and a high frequency (alpha and beta) decrease in the frontal and temporal areas (Marshall & Fox, 2004).

Furthermore, children who experienced early intra-familial physical abuse, have smaller volume in orbitofrontal areas, as revealed by MRI technique (Hanson et al., 2010). These areas are particularly important because they play a key role in emotional and motivational control and they are included in the brain network that oversees adaptation toward environmental changes (Hanson et al., 2010).

Even medial subcortical areas, such as amygdala and hippocampus, show a reduced volume in children who have suffered lack of care, abuse and were raised in a socio-economic disadvantaged conditions (Hanson et al., 2014, 2011).

By measuring maltreated children's P3b ERP component in response to others' facial expression of emotions, authors detected greater victim's attention to the angry faces, correlated to their increased Corrugator activation (Shackman & Pollak, 2014). These results suggest that these children are more negatively influenced by others' angry facial expressions.

Some studies focused on maltreated children's facial mimicry responses to others' emotion, by means of EMG recording of facial muscles activations. As previously extensively described, facial mimicry represent an implicit index of victims' empathic responses.

Facial Mimicry of abused children recorded during an aggression trials toward peers, shows greater Corrugator activation compared to non-abused children in response to others' facial expressions of emotions. This enhanced muscular response is accompanied by more aggressive attitudes, (Shackman & Pollak, 2014). An opposite pattern is found in women who suffer childhood sexual or physical abuse by someone close, such as a parent (i.e., high-betrayal abuse), who show greater facial mimicry to joy facial expressions, and less facial mimicry to anger facial expressions compared to women

with low- or no-betrayal abuse (i.e., childhood sexual or physical abuse by someone not close or no abuse in childhood) (Reichmann-Decker, DePrince, & McIntosh, 2009).

Recently, some studies investigated how childhood adverse experiences can influence children's autonomic regulation in social and non-social conditions, measured by RSA. Abused children show lower RSA responses than controls during social interaction with adult figure of reference (Oosterman et al, 2010; Skowron et al, 2014), which suggests the implementation of behavioral defensive strategies belonging to the sympathetic system.

Moreover, when children reared in neglected family are submitted to the "Strange Situation" (an experimental procedure used to evaluate the child's Attachment Style, during which the mother-child dyad is subjected to different situations eliciting potential social stress; Ainsworth et al., 1970), their RSA levels increase during separation and decrease during rapprochement phases, showing less vagal regulation than children with secure attachment (Oosterman et al., 2010).

Conflictual interactions induce increased RSA level in abused children's, indicating a defensive reaction towards aggressive behaviors and maltreatment effects (Gordis, Feres, Olezeski, Rabkin, & Trickett, 2010).

Another research shows that abused children have less inhibitory control, supported by low RSA level, during a joint task (Skowron et al., 2014).

Finally, early neglected children, compared to those reared in family, show lower levels of Arginine Vasopressin, an essential peptide for the creation of social relations and for the emotion regulation of behaviors (Fries, Ziegler, Kurian, Jacoris, & Pollak, 2005).

These experimental results lead to the conclusion that the exposure to traumatic experiences in infancy reduces the parasympathetic regulation, that promotes social

relations (Fries et al., 2005) Despite all this evidence, it is important to highlight that the results of certain traumatic experiences depend on protective factors, such as resilience and the support of other people (Glaser, 2000; Oppong Asante-Weitz & Meyer, 2015). A recent study focus on both facial mimicry (measured by facial EMG) and vagal regulation (measured by RSA) in response to the observation of facial expressions of emotions in an adolescent sample of street-boys exposed to prolonged conditions of both maltreatment and neglect (Ardizzi et al., 2013). This was the first empirical study investigating the effects of early adverse experiences on these two automatic processes related to the empathic understanding of others' emotions and to the behavioral regulation in social contexts. Results demonstrate a profound alteration of both facial mimicry and vagal regulation of street-boys compared to controls. Street-boys showed a significant reduction of congruent facial mimicry responses (i.e., Corrugator activation for negative facial expressions of emotions, and Zygomaticus activation for positive facial expression of emotion), as well as absence of Corrugator modulation between positive and negative facial expressions. Furthermore, lower RSA value at rest condition and an ineffective RSA suppression during the observation of non-threatening facial expressions of emotions (i.e., fear, joy and sadness expressions) were evidenced among street-boys compared to control group (Ardizzi et al., 2013). These results suggest that the early exposure to neglect and maltreatment affects the physiological mechanisms strictly related to the empathic understanding of others' emotions and the behavioral regulation in social contexts (Ardizzi et al., 2013).

Taken together, from these introductive considerations, it clearly emerges that childhood adverse experiences and growth background play a primary role in the

development of children's emotions expression and recognition skills (see "Emotions and early social interactions" paragraph) conditioning, by means of specific mechanisms (see "The environment and the Human Development" paragraph), the functionality of neural networks related to these abilities. Moreover, the relationship with caregivers, in the first period of life, affects the attachment bond (see "Attachment and emotions" paragraph), which in turn influences the child's ability to interact with and understanding others (see "Empathy and Facial Mimicry" paragraph). Finally, empathic resonance and behavioral regulation in social contexts are altered by the exposure to adverse experiences in childhood (see "Street Children" paragraph).

In summary, growing up as a street-child can affect the empathic understanding of others' emotions and, consequently, the adequacy of behavioral responses in reference to the social context can be dysfunctional.

The aim of the study

The aim of this study was to investigate whether early adverse experiences could interfere with facial mimicry and the autonomic regulation of social behaviors in a sample of street-children, extending previous research focused on an adolescent sample of street-boys.

In other words, the goal of this study is to inquire how being exposed to repeated adverse experiences in childhood, such as maltreatment, abuse and neglect, can influence the trajectories of social development.

To this aim a physiological task was conducted in a group of street-children and in an age-matched control group. During the task facial electromyography (EMG) -a marker of facial mimicry - and respiratory sinus arrhythmia (RSA) - an autonomic index of

social predisposition and self-regulation in social conditions - were recorded in response to positive and negative facial expressions of emotions.

Material and methods

Participants

Sixty Sierra Leonean children were recruited for the study, 30 were street-children directly recruited in the street or in schools enrolling abandoned children. The other thirty 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-groups 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 study. Moreover, children resulting outliers (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 consisted of 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.

Stimuli

Stimuli employed in the experiment were the same 64 video-morphing adopted in Ardizzi et al., (2013). They consisted of 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.). 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) and they were asked to carefully observe the video stimuli.

Procedure

The experimental session consisted of a physiological experiment that was a simple perceptive task conducted to record Facial Electromyography (Facial EMG) and Respiratory Sinus Arrhythmia (RSA) responses to the stimuli.

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).

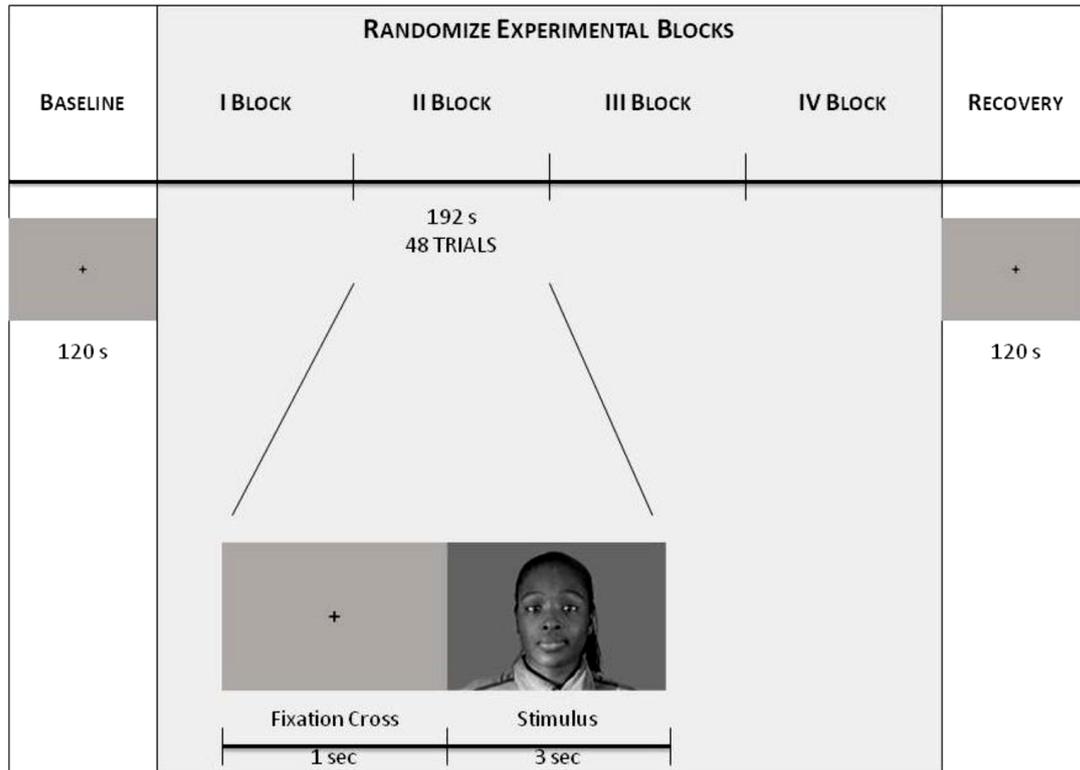


Figure 1. Graphical representation of the physiological experiment procedure.

The experiment consisted of four “condition-blocks” (each lasting 192 sec) and two “baseline blocks” (each lasting 120 sec) (Figure 1). 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 EMG

We used 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 was 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). The total average percentage of removed trials was $18.68\% \pm 6.10$. The screened EMG signal was then elaborated to extract the amplitude and the latency of participants' facial muscular responses to facial expressions of emotions following the subsequent procedures.

Facial EMG Amplitude extraction

Following standard practice, the average amplitude of the EMG signal was obtained via root-mean-square method applied on epochs lasting 500 msec (1 pre-stimulus onset epoch and 6 post-stimulus onset epochs). Facial EMG amplitude response (expressed in microvolts, μV) to the different facial expressions of emotions was then computed as change scores between activity during each 500 msec of the 3 sec post-stimulus onset period and the 500 msec immediately preceding stimulus onset (Fridlund & Cacioppo, 1986).

Facial EMG onset latency extraction

In order to obtain an accurate estimation of EMG latency, the EMG signal was segmented in epochs lasting 50 msec (10 pre-stimulus onset epochs and 60 post-stimulus onset epochs), on which by the root-mean-square method was applied to extract the signal amplitude. Onset latency was defined by more than 2 standard deviation (SDs) above the baseline level (average of 10 pre-stimulus onset epochs) for a minimum of 100 msec.

Respiratory Sinus Arrhythmia

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 $\ln(\text{msec})^2$] 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 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 amplitude 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.

In order to assess between groups differences in facial EMG latency 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) as within factor.

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) 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.

Moreover, 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 (Patriquin et al., 2011).

Finally, possible correlations between facial mimicry and vagal regulation during the visualization of positive and negative facial expressions of emotions were estimated separately for the two groups by means of two Pearson's Correlations analyses. Correlation were performed between Facial EMG amplitude and the RSA suppression values recorded for each condition; and between Facial EMG onset latency and RSA suppression values recorded for each condition. Only significant correlations are reported in results session.

Results

Facial EMG Amplitude

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 ($-0.09 \mu\text{V}$, SE 0.16) was significantly lower than corrugator EMG activity measured in response to both angry ($0.63 \mu\text{V}$, SE 0.20; $p = 0.03$), and fear facial expressions ($0.75 \mu\text{V}$, SE 0.25; $p = 0.01$). No significant difference was found between joy and sadness corrugator EMG activity ($0.48 \mu\text{V}$, SE 0.12; $p = 0.14$). This last result was explained considering Emotion by Group Interaction (Figure 2). 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 $p_s > 0.05$).

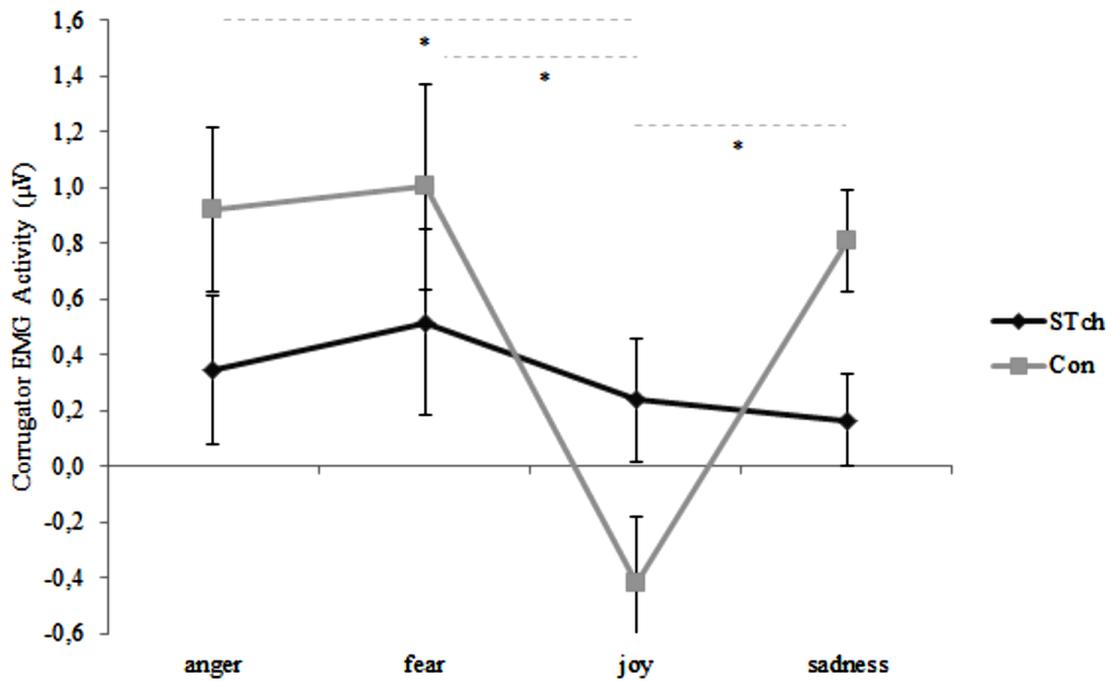


Figure 2. Corrugator EMG Activity for Street-Children group (STch) and Control group (Con) during presentation of facial expressions of emotions. * = $p < 0.05$. Error bars represent SE.

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: $\epsilon = 0.37$; Epoch: $\epsilon = 0.23$; Emotion by Epoch: $\epsilon = 0.09$). 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; $p = 0.01$).

Facial EMG onset latency

Corrugator Supercilii – Repeated-measures ANOVA conducted on Corrugator onset latency did show neither significant main effects of Group ($F_{1,39} = 1.72$, $p = 0.20$; $\eta^2_p = 0.04$), Sex ($F_{1,39} = 0.15$, $p = 0.90$; $\eta^2_p = 0.000$) and Emotion ($F_{3,39} = 0.76$, $p = 0.52$; $\eta^2_p = 0.02$) nor significant interactions (Emotion*Group: $F_{3,39} = 0.26$, $p = 0.85$, $\eta^2_p = 0.01$; Emotion*Sex: $F_{3,39} = 0.51$, $p = 0.68$; $\eta^2_p = 0.01$; Emotion*Group*Sex: $F_{3,39} = 0.36$, $p = 0.78$; $\eta^2_p = 0.01$).

Zygomaticus Major – Repeated-measures ANOVA conducted on Zygomaticus onset latency did show neither significant main effects of Group ($F_{1,40} = 0.99$, $p = 0.32$; $\eta^2_p = 0.02$), Sex ($F_{1,40} = 0.04$, $p = 0.83$; $\eta^2_p = 0.001$) and Emotion ($F_{3,40} = 1.92$, $p = 0.13$; $\eta^2_p = 0.05$) nor significant interactions (Emotion*Group: $F_{3,40} = 1.64$, $p = 0.18$, $\eta^2_p = 0.04$; Emotion*Sex: $F_{3,40} = 0.66$, $p = 0.58$; $\eta^2_p = 0.02$; Emotion*Group*Sex: $F_{3,40} = 0.34$, $p = 0.80$; $\eta^2_p = 0.01$).

Baseline and Recovery RSA

Bonferroni corrected t-tests (with $\alpha 0.05 = 0.016$) comparing STch and Con groups' Baseline (STch: $5.90 \ln(\text{msec})^2$, SE 0.34; Con: $6.15 \ln(\text{msec})^2$, SE 0.27) and Recovery (STch: $5.90 \ln(\text{msec})^2$, SE 0.28; Con: $6.08 \ln(\text{msec})^2$, 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 ($6.01 \ln(\text{msec})^2$, SE 0.22) and Recovery RSA ($5.98 \ln(\text{msec})^2$, SE 0.19) values resulted not significant ($t_{83} = -0.11$, $p = 0.91$).

Correlation between Baseline RSA and RSA suppression values

Two-tailed Pearson’s correlations performed for STch group (Table 2 and Figure 3) 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; * = $p < 0.05$

STch Group

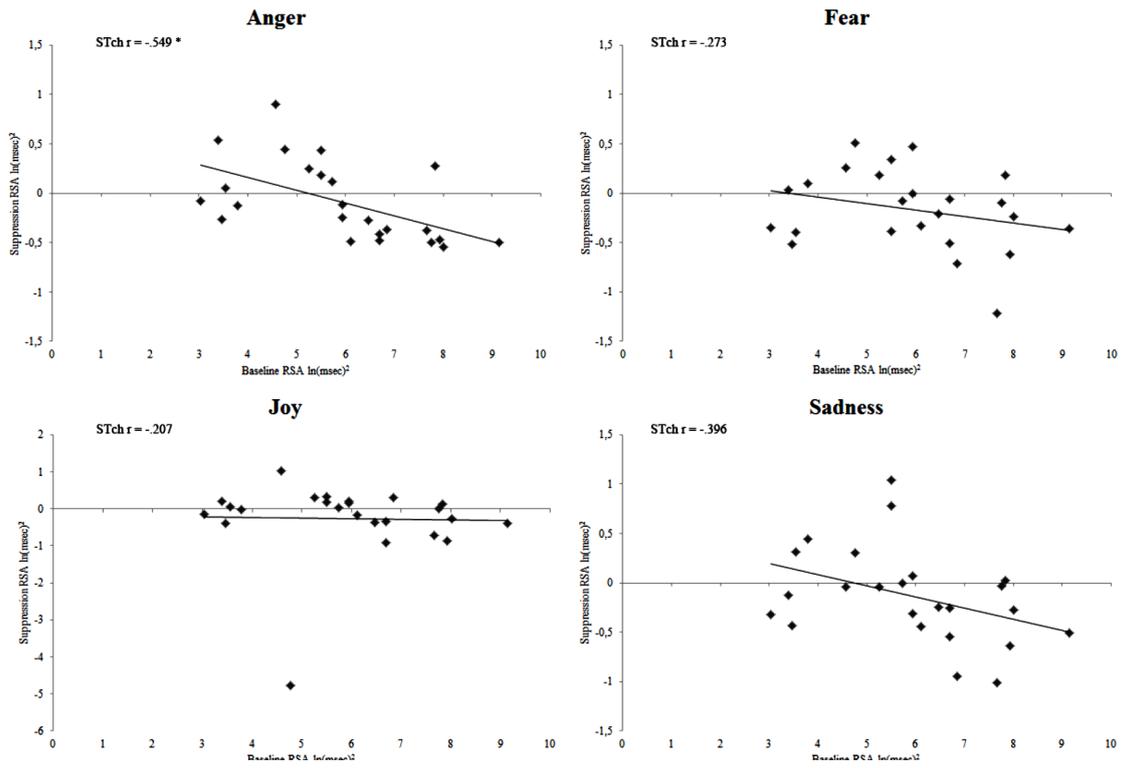


Figure 3. Plots of correlation between Mean Baseline and Suppression RSA values for street-children Group displayed emotion by emotion. STch = street-children. * = $p < 0.05$.

On the contrary, two-tailed Pearson's correlations performed on Con group (Table 3 and Figure 4) 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; * = $p < 0.05$

Con Group

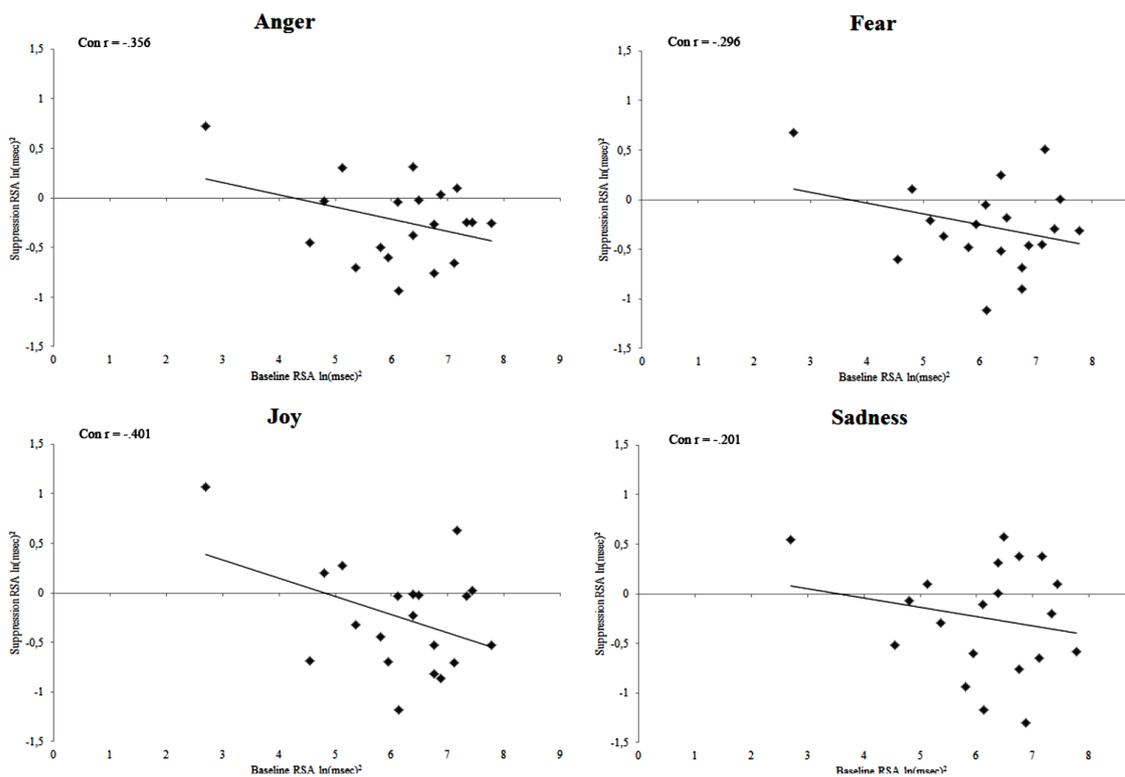


Figure 4. Plots of correlation between Mean Baseline and Suppression RSA values for control Group displayed emotion by emotion. Con = Control. * = $p < 0.05$.

Correlation between Facial EMG onset latency and RSA suppression values

Two-tailed Pearson's correlations performed for STch group (Figure 5) demonstrated a significant negative relation between Corrugator muscle Facial EMG onset latency and Suppression RSA in response to sadness facial expressions ($r_{24} = -0.46$; $p = 0.023$).

On the contrary, two-tailed Pearson's correlations performed on Con group revealed an absence of significant relations between muscles Facial EMG onset latencies and Suppression RSA in response to all facial expressions of emotions.

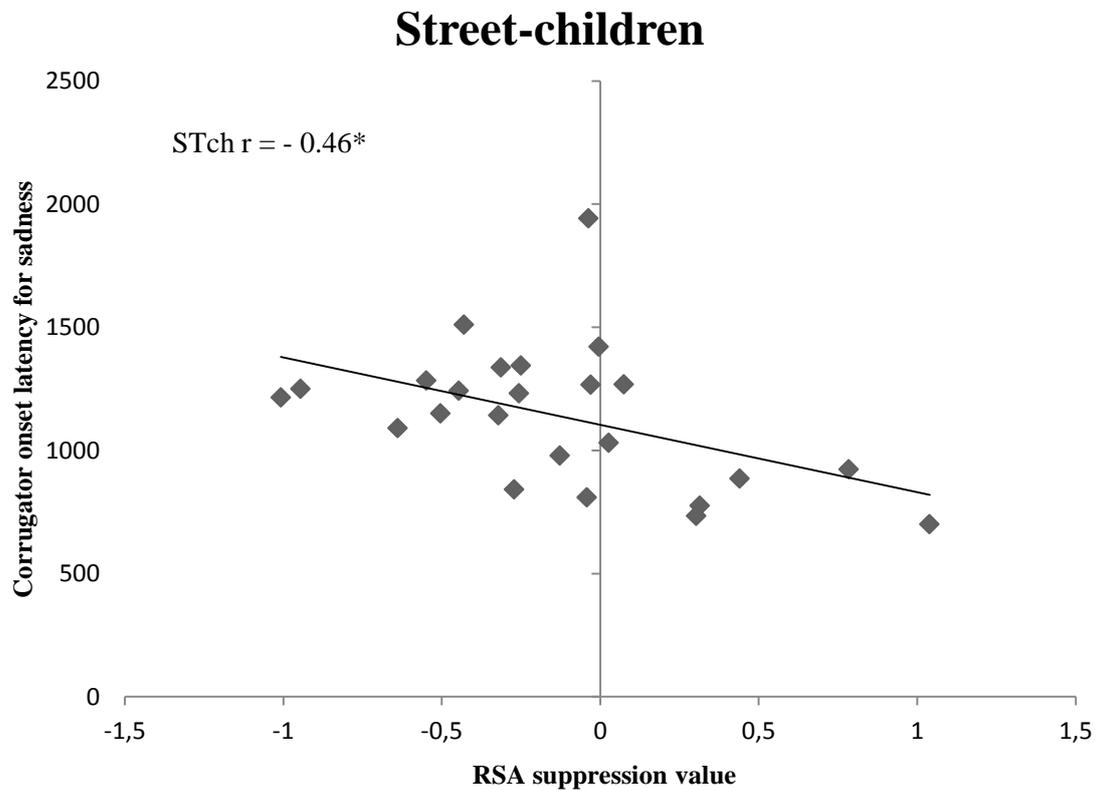


Figure 5. Plot of correlation between Facial EMG onset latency and RSA suppression values for Street-children in response to sadness facial expressions.

Discussion

The aim of this study was to investigate whether being exposed to adverse experiences during childhood can influence the implicit and automatic physiological processes related to the empathic understanding of others' emotions and to the autonomic regulation of social behaviors (i.e., facial mimicry and vagal regulation). In other words, this study allows to better understand if prolonged experiences of maltreatment, abuse and neglect in childhood, can interfere with the development of children's specific social abilities.

To this aim a physiological task was conducted in a group of street-children and in an age-matched control group. During the physiological task facial EMG - a marker of facial mimicry - and RSA - a vagal autonomic index of social predisposition and self-regulation - were recorded in response to the observation of facial expressions of emotions. Results demonstrate that the exposure to repetitive adverse experiences induces, in a sample of street-children, a specific alteration of the investigated physiological mechanisms, in particular, in those involved in the empathic understanding of others' emotions. These results are particularly interesting if we consider the different effects observed in an older sample of street-boys exposed to the same experimental paradigm and to similar life conditions but for more protracted periods (Ardizzi et al., 2013), as discussed below.

In the present study, street children's facial EMG amplitude and onset latency do not differ from controls. These results demonstrate that neither the amplitude nor the activation onset of the implicit facial mimicry responses to others' facial expressions are influenced by early adverse experiences at this age, suggesting a general preservation of

one of the physiological processes underlying the empathic understanding of others' emotions.

On the contrary, street-children, but not controls, show an absence of positive/negative modulation of Corrugator Facial Mimicry.

As previously mentioned in Introduction, Corrugator muscle is usually activated by negative stimuli (i.e. anger, fear and sadness facial expressions) and suppressed by positive stimuli (i.e. joy facial expressions). On the contrary, Zygomaticus muscle is activated by positive stimuli and suppressed by negative ones (Dimberg, Thunberg, & Grunedal, 2002). These different activations are automatic and spontaneous (Dimberg et al., 2002). Furthermore, it has been demonstrated that the positive/negative modulation of Corrugator and Zygomaticus muscles is related to the implicit attribution of stimuli emotional valences (Sato, Fujimura, Kochiyama, & Suzuki, 2013).

Few studies reported similar effects both in clinical and not clinical samples. Specifically, an altered modulation of the Corrugator responses during the view of positive and negative facial expressions was observed in children suffering from Autism Spectrum Disorders (McIntosh et al., 2006), who also showed a deficit in emotion recognition (Baron-Cohen, 2010). ASD children do not show a differentiated modulation of the Corrugator response between positive and negative facial expressions. Furthermore this altered pattern of response results was strictly connected to their emotion recognition skill (McIntosh et al., 2006).

These results suggest that being exposed to adverse experiences during childhood firstly influence the physiological mechanism associated with valence attribution, rather than the overall facial mimicry automatic responses. A different pattern of results is described among street-boys (Ardizzi et al., 2013) who, following a more protracted

exposure to adverse experiences of maltreatment and neglect, showed a comprehensive alteration of facial mimicry responses (i.e., EMG amplitude and positive/negative modulation).

Another interesting result of the present study, is the distinctive influences of adverse experiences on Corrugator and Zygomaticus muscles. In fact, only the first one shows an alteration of his activation to positive and negative facial expressions. On the contrary, Zygomaticus modulation to positive and negative facial expressions of emotions, as well as, Zygomaticus response amplitude, are not significantly different between street-children and controls. It is possible to suppose that facial mimicry responses to positive facial expressions of emotions, like joy, are more resistant to external environmental influences.

Other intriguing considerations can be outlined considering participants' vagal responses at rest conditions and during the visualization of facial expressions of emotions. Between-groups differences in Baseline and Recovery RSA values were not found. It is important to note that, again, lower RSA values at rest condition were previously described in adolescent sample of street-boys (Ardizzi et al., 2013). In the present study, an opposite vagal modulation during the visualization of positive and negative facial expressions of emotions was evidenced between the two groups. Street-children show a significant correlation between Baseline RSA and RSA suppression values during the observation of angry facial expressions. Differently, control children did not show any significant correlation between these two indexes. These results are particularly interesting for the aim of the present study, because vagal suppression in response to threatening environmental stimuli (e.g., angry facial expressions) represents a functional autonomic modulation, which assumes an adaptive activation of defensive

behavioral strategies (Porges, 2003). Higher baseline and greater RSA suppression are considered indexes of a better ability to respond adaptively to environmental requests (Thayer & Lane, 2000 Thayer, 2012).

Accordingly, individuals with higher baseline RSA should show greater RSA suppression to meet metabolic demands of taxing environmental conditions, including threatening stimuli. By applying these assumptions to the present experimental paradigm, a significant correlation between Baseline RSA values and Suppression RSA values to angry facial expressions was expected, especially among controls. Coherently, in our previous study healthy adolescents showed significant correlation between RSA values recorded at rest condition and RSA suppression values during angry facial expressions observation, but not with RSA suppression values recorded in response to non-threatening facial expressions (i.e., joy, fear and sadness facial expressions; Ardizzi et al., 2013). Considering these interpretations and the previous data, the present results appear to be at least unexpected. The adaptive modulation of vagal responses to angry facial expressions, suggests that living in a deprived background and being exposed to traumatic events promote the development of an early functional synchronization between external environment and vagal regulation, which in normal conditions is shown later in development. In other words, the early exposure to adverse experiences promote an early vagal regulation in order to adaptively respond to the adverse conditions.

This hypothesized earlier development of autonomic regulation is also sustained by the evidence that street-children show significant correlations between RSA suppression values to negative facial expressions (i.e., angry, fear and sadness facial expressions), whereas, controls show an indiscriminate correlations between RSA suppression values

to all facial expressions of emotions (i.e., both positive and negative facial expressions). This demonstrates that street-children's, but not controls', vagal response is influenced by stimuli affective valence.

Although there are few studies directly investigating facial mimicry and vagal regulation, a link between emotional facial expressivity and cardiac vagal tone is suggested. Specifically, a reduced facial expressivity under distressing conditions, characterized by a vagal withdrawal (i.e., greater RSA suppression), was described (Porges, Doussard-Roosevelt, & Maita, 1994; Porges, 2001). Considering both these results and the between-groups differences demonstrated in the present study, correlation analyses between RSA suppression values and Corrugator EMG amplitude, as well as, between RSA suppression values and Corrugator onset latencies were conducted separately for street-children and controls. A significant negative correlation between RSA suppression values and Corrugator onset latencies is found in response to sadness facial expression among street-children. Only in this group, longer Corrugator onset latency corresponds to greater RSA suppression values, in response to sadness facial expressions.

In a study involving children suffering from Disruptive Behavior Disorders (DBD) (De Wied et al., 2009) facial EMG responses during the observation of video clips inducing sadness, anger and happiness, as well as, resting RSA values were recorded. Results showed a significant positive correlation between resting RSA values and Corrugator EMG responses to anger stimuli in healthy controls ($r=0.50$; $p=0.009$), and a marginally significant positive correlation between resting RSA values and Corrugator EMG responses to sadness stimuli in DBD patients ($r=0.32$; $p=0.07$) (De Wied et al., 2009).

These results strengthen the direct relation between vagal regulation and facial mimicry among healthy children, and partially also among participants with behavioral disorders. Our results are in agreement with these conclusions and add interestingly information on onset latency, that are relevant in facial mimicry responses. We demonstrate that lower RSA values correlate with delayed muscular activations during sadness visualization, only among street-children. This result suggests that others' sadness facial expressions represent, for street-children, a particularly stressful social stimulus for which a delayed facial mimicry is coupled with a relevant vagal withdrawal. Previous studies demonstrated that sadness is the less identified facial expressions among maltreated adolescents (Ardizzi et al., 2013) and that it is also denied in an adult sample of former child-soldiers (Umiltà et al., 2013). Taken together these results confirm that facial expressions of sadness represent for maltreated, abused and traumatized samples a particularly unmanageable emotion associated to both low explicit recognition performance and implicit empathic response. Further studies are required to better explain why sadness assumes such great relevance in these specific samples. Finally, it is important to mention the absence of an expected, based on previous literature (De Wied et al., 2009; Porges, Doussard-Roosevelt, & Maita, 1994; Porges, 2001), significant correlation between RSA suppression values and Corrugator EMG amplitude during the observation of anger facial expressions among controls. This could be explained by a still immature vagal regulation in control children, as here described and demonstrated by the previously reported analyses.

Conclusion

The results of the present study show that the exposure to high levels of maltreatment and neglect during childhood, affects victims' Facial Mimicry and vagal regulation responses to facial expressions of emotion. Specifically, in children exposed to adverse experiences we observed an alteration of implicit emotional valence discrimination, demonstrated by the absence of Corrugator responses modulation between negative and positive facial expressions. Moreover, being exposed to early maltreatment and neglect leads to an earlier development of mechanisms that functionally synchronize the vagal regulation to the environment, especially in response to threatening (i.e., angry facial expressions) and unmanageable (i.e., sadness facial expressions) emotions.

Comparing the results obtained investigating a sample of street-children, with those described in an older adolescent population of street-boys exposed to similar adverse conditions but for longer time, an additive effect of negative experiences duration could be hypothesized. The street-boys' more protracted exposure to high levels of maltreatment and neglect compared to street-children may be responsible for the greater impairment in facial mimicry and vagal regulation observed in the former population.

Further investigations directly comparing populations exposed to different degrees of prolonged traumatic experiences are needed to confirm this hypothesis.

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).

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