Corso di Laurea Magistrale in Psicobiologia e Neuroscienze Cognitive

Effetti del trauma sui meccanismi di esplorazione visiva di espressioni facciali emotive: uno studio eye-tracker ed etnopsichiatrico su popolazioni di minori sopravvissuti all'epidemia di Ebola in Sierra Leone.

The impact of trauma on visual exploration patterns of facial expressions of emotions: an eye-tracker and ethnopsychiatric study conducted among underage Ebola virus disease survivors in Sierra Leone.

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ABSTRACT

Ad oggi, il bias nel riconoscimento dell'espressione facciale della rabbia, consistente nell'erronea sovra-identificazione dell'emozione rabbia quando altre espressioni facciali emotive negative vengono visualizzate, è abbastanza conosciuto. Diversi studi empirici hanno investigato questo fenomeno attraverso differenti paradigmi e coinvolgendo campioni di minori, vittime di differenti esperienze traumatiche. Comparando tutti questi risultati sembrerebbe che il bias nell'esplicito riconoscimento dell'espressione facciale della rabbia sia conseguenza dell'esposizione, sia prolungata sia acuta, ad eventi traumatici occorsi duranti l'infanzia. Nonostante questa abbondanza di studi, ad oggi resta incerto se questo bias possa essere interpretato come una generale tendenza di risposta delle vittime oppure come effetto di uno specifico ancoraggio, da parte dei meccanismi percettivi delle vittime, a cue facciali significativi per il riconoscimento della rabbia.

Il principale obiettivo del presente studio, dunque, era quello di esplorare ulteriormente i meccanismi che sottendono il bias nel riconoscimento delle espressioni facciali di rabbia. A questo proposito sono stati reclutati un campione di minori sopravvissuti all'epidemia di Ebola e un campione di controllo di pari, entrambi provenienti dalla Sierra Leone. Il PTSD Checklist per il DSM-5 (PCL-5), l'Impact of Event Scale-revised (IES-R) e il Cognitive Emotion Regulation Questionnaire short version (CERQ-short) sono stati preventivamente tradotti e validati seguendo il processo di adattamento cross-culturale. Successivamente tali questionari sono stati somministrati ad entrambi i gruppi di partecipanti per valutare la presenza della sintomatologia correlata al PTSD e a segni psicopatologici derivanti dall'esposizione all'epidemia di Ebola. Inoltre i partecipanti hanno preso parte ad un compito, a scelta forzata, di riconoscimento di espressioni facciali emotive. Durante lo

svolgimento del suddetto compito i pattern di esplorazione visiva dei partecipanti sono stati registrati avvalendosi della tecnica di eye-tracking. Data la rilevanza del bias nel riconoscimento della rabbia, l'intento del presente studio era, in particolare, quello di investigare i pattern di scanning visivo messi in atto da ambedue i gruppi durante il riconoscimento delle espressioni facciali emotive, sia nelle performance corrette sia in quelle errate in favore del bias.

I punteggi dei questionari hanno confermato la natura traumatica dell'aver contratto il virus Ebola e delle relative avversità in quanto in grado di indurre, nel gruppo di Sopravvissuti al contagio, sequele psicopatologiche correlate al PTSD e specifiche strategie di coping. Inoltre il gruppo di Sopravvissuti ha mostrato, in modo significativo, una maggiore sovra-attribuzione dell'etichetta rabbia rispetto al gruppo dei Controlli, confermando che il bias nel riconoscimento della rabbia emerge non solo in seguito a prolungate esperienze traumatiche, ma anche in seguito a traumi di tipo acuto. Un risultato del tutto nuovo ottenuto dal presente studio è costituito dalla significativa correlazione tra il tasso di presenza del bias e il punteggio ottenuto nel questionario IES. Ciò conferma l'affidabilità dell'adattamento cross-culturale dei questionari e dimostra la forte correlazione tra il bias per la rabbia e i sintomi del PTSD. E' importante notare che questa è la prima volta che scale cliniche per la valutazione del PTSD sono state tradotte e adattate ad un Paese africano e nello specifico alla Sierra Leone.

La nostra aspettativa di trovare caratteristici pattern di esplorazione visiva, soprattutto in termini di localizzazione, correlati alla presenza del bias di sovra-attribuzione della rabbia, è stata confermata. Nonostante tutti i partecipanti abbiano esibito scan paths differenti da quelli occidentali, il gruppo dei Sopravvissuti, e non quello dei Controlli, ha messo in atto pattern di esplorazione simili in entrambe le performance, quella corretta e quella errata in favore del bias per la rabbia. I Sopravvissuti hanno osservato l'occhio sinistro *significativamente più spesso e più a lungo dei Controlli. Inoltre lo stesso pattern è stato osservato durante le performance caratterizzate dalla presenza del bias, specialmente in risposta alla visualizzazione della tristezza, che si conferma come l'emozione più rilevante nell'elicitare il bias per la rabbia. Sebbene questo sia uno studio preliminare, sembra che i Sopravvissuti fossero più sensibili ai cue correlati alla rabbia, i quali possono essere trovati soprattutto nella regione oculare piuttosto che nella regione della bocca. Infine, alcune peculiarità emerse dalle analisi delle risposte comportamentali del gruppo traumatizzato, portano a ipotizzare che esperienze traumatiche differenti, almeno in termini acuto/cronico, possano alterare in modo differente il riconoscimento delle emozioni.*

To date, the bias in the recognition of angry facial expressions, consisting in the erroneous over-identification of anger when other negative facial expressions are visualized, is quite well-known. Several empirical studies investigated this phenomenon with different paradigms and involving samples of underage victims of different traumatic experiences. Comparing all these results, it appears that the bias in the explicit recognition of angry facial expressions is a consequence of both acute and prolonged exposure to traumatic events during childhood. Despite this plethora of studies, to date it remains unclear whether this bias can be interpreted as an overall victims' response tendency or as an effect of the specific tuning of victims' perceptive mechanisms to angry facial expressive cues.

Therefore, the main aim of the present study was to further explore some of the mechanisms likely involved in the biased recognition of angry facial expressions. To accomplish this purpose, a sample of underage Ebola virus disease survivors and a sample of peer controls, both coming from Sierra Leone, were recruited for the study. The PTSD Checklist for DSM-5 (PCL-5), the Impact of Event Scale-revised (IES-R) and the Cognitive Emotion Regulation Questionnaire short version (CERQ-short) were first translated and validated following the cross-cultural adaptation process. These questionnaires were then administered to both groups of participants in order to assess the presence of PTSD symptoms and psychopathologic signs caused by Ebola outbreak exposure. Furthermore, participants took part to a forced-choice facial expressions recognition task. During the task, participants' visual exploration patterns were recorded by means of an eye tracker. Given the relevance of the bias in the recognition of anger, the intent of the present study was, in particular, to investigate differences in the visual scanning patterns used by the two groups during both the correct and the biased recognition of facial expressions of emotions.

Questionnaire scores confirmed the traumatic nature of Ebola infection and related adversities, as they induced PTSD-related *sequelae* and specific coping strategies among Ebola survivors. Moreover, Survivors showed a significant higher over-attribution of anger than Controls, confirming that the bias in the recognition of anger arises not only from prolonged traumatic experiences but also from acute trauma. A completely new result of the present study was the significant correlation between the bias rate in response to sadness and IES scoring, confirming the reliability of the cross-cultural adaptation of the questionnaire and demonstrating the strong correlation between the anger bias and PTSD symptoms. It is important to note that this is the first time that clinical scales for the evaluation of PTSD have been translated and adapted to an African country and specifically to Sierra Leone.

Our prediction to find characteristic visual exploration patterns, especially in terms of location, related with the anger over-attribution bias was confirmed. Even if all participants clearly exhibited scan paths different from the western ones, Survivors, but not Controls, displayed a similar exploration pattern in both correct and biased recognition performances. Survivors looked to the eye-left significantly more often and for longer time than Controls. Furthermore, the same pattern was observed during biased performances, especially in response to sadness, which confirmed itself as the most relevant emotion in eliciting the bias for anger. Although this is a preliminary study, it seems that Survivors were more sensitive to anger-related cues, especially found in the eye region rather than in the mouth region. Finally, some peculiarities emerged from the behavioral responses analyses of the traumatized group, leading to hypothesize that different traumatic experiences, at least in acute/chronic terms, can differently affect the correct recognition of emotions.

1. INTRODUCTION

1.1 An overview of trauma psychological impact – from PTSD diagnosis to the bias in the recognition of the facial expression of anger.

The diagnostic construct of Post Traumatic Stress Disorder (PTSD) was formulated for the first time in the late 1970s to capture the psychological suffering of millions of soldiers who had just returned from the Vietnam war (Van der Kolk, 2002). Events to which those soldiers were exposed were labeled as "traumatic", due to their direct connection with the subsequent psychopathological reactions proper of PTSD symptomatology. Until then, trauma as etiological factor was mostly ignored. Over the next decades, this diagnostic construct has been subjected to adjustments. Unlike the previous versions, DSM-V (American Psychiatric Association, 2013) lists PTSD under a new separate category (Trauma-and-Stressor-Related Disorders) with other diagnosis arising from the exposure to distressful and traumatic events. According to DSM-V traumatic events, which can occur at any age, include exposure to war, threatened or actual physical assault, severe motor vehicle accidents, threatened or actual sexual violence, being kidnapped, taken hostage, terrorist attack, torture, incarceration, human-made or natural disasters like in the present study (American Psychiatric Association, 2013). These events can be directly experienced, witnessed or indirectly experienced through learning that they happened to close relatives and friends (Criterion A, DSM-V).

Victims of such traumatic or stressful events can exhibit different phenotypes: anxiety or fear-based symptoms, anhedonic and dysphoric symptoms, externalized anger and aggressive symptoms, or dissociative symptoms. Individuals with PTSD are 80% more likely than those without PTSD to manifest symptoms meeting diagnostic criteria for at least one other mental disorder (e.g., major depression, bipolar disorder, anxiety, or substance use disorders). The high incidence of psychiatric comorbidity of PTSD patients is demonstrated among both adults and minors but with different profiles. Underage victims, especially when adolescent, mostly show oppositional defiant disorder and separation anxiety disorder (American Psychiatric Association, 2013)

The traumatic event can be re-experienced in different ways (Criterion B, DSM-V). A common symptom consists in a recurrent, involuntary and intrusive memory related with the traumatic event. Commonly, it can appear in the form of distressing dreams that replay the event or facts which are thematically connected to it. Another re-experience symptom can be represented by dissociative states often referred to as "flashback", in some cases accompanied by loss of orientation and awareness of the present context. Moreover, internal stimuli such as memories, thoughts, feelings but also external stimuli such as people, places, conversations, objects linked to the trauma are typically strongly avoided (Criterion C, DSM-V).

In addition, PTSD patients can be affected by cognitive and umoral alterations (Criterion D, DSM-V), like dissociative amnesia to some key features of the traumatic event, persistent and exaggerated negative beliefs, distorted cognitions about the causes and consequences of the event, prolonged negative emotional state and inability to experience positive emotions, loss of interest in pre-traumatic significant activities, feeling alienated from others (detachment or estrangement). Finally, trauma-related alterations in arousal and reactivity can be recognized (Criterion E, DSM-V). These changes include: irritable or aggressive behaviors, self-destructive or reckless behaviors, hypervigilance, exaggerated startle responses, problems in concentration and sleep disturbances.

The onset of PTSD symptoms can vary according to victims' age. Prescholar children (less than 6 years) may report scary dreams without contents directly related to the trauma. More easily, they may express these contents through play and storytelling. Among children, avoidance can mostly be seen in a reluctance to play, to explore their environment and in difficult engagement in new activities. Scholar children and adolescents may refer of themselves as cowards. Adolescents can also experience future disillusionment and beliefs of being socially undesirable. For sure, irritable and aggressive behaviors, sometimes associated with specific conduct disorder, can negatively affect peer relationships.

Since the 1990s the definition of "developmental trauma", described as protracted and repeated aberrant experience occurring during childhood, has gained increased attention culminating in the formulation of the new diagnostic nomenclature of Complex PTSD (Van der Kolk et al., 1996; Roth et al., 1997). This diagnostic criterion was specifically proposed to include the clinical consequences of being exposed to repeated and cumulative experiences of childhood abuse (sexual, emotional, and physical) and neglect (emotional or physical absence of adequate caregiving during childhood). To date, the American Psychiatric Association (2013) includes neglect and deprivation experiences, described as persistent lack of comfort, stimulation, and affection by adult caregivers, in the diagnostic criteria for reactive attachment disorder and disinhibited social engagement disorder, both grouped in the main category of Trauma-and-Stressor-Related Disorders. Several studies demonstrated that children face their traumatic experiences expressing a constellation of symptoms in addition to the classical PTSD symptoms (see for example Van der Kolk et al., 2001; Cook et al., 2005; Cloitre et., 2009). Childhood adversities result in altered developmental processes affecting an adaptive emotion regulation and connected social behavioral and self-regulation skills (Cloitre, 2009; 2013). Other dysfunctional findings concern attention and consciousness, self-perception, system of meaning, somatization (Sar, 2011).

Deficits in social, affective and physiological regulation have been confirmed among adolescents with adverse and protracted childhood experiences (Ardizzi et al., 2013). These individuals exhibited altered explicit emotion recognition, reduced spontaneous facial mimicry to facial expressions of emotions and dysfunctional recruitment and regulation of the myelinated component of the vagal nerve, which normally promotes positive social predisposition. Concerning alterations in emotion recognition, which can occur both in children and young adults with a history of childhood abuse, an experience-specific information-processing bias for angry facial expressions to the detriment of other facial expressions of emotions should be highlighted. Previous research has shown that victims of trauma's attention is preferentially and specifically allocated to facial expressions of anger, much less so to facial expressions of joy and sadness. Furthermore, higher sensitivity in the detection of facial expressions of anger, even at low levels of emotional intensity, was exhibited among victims of trauma (Gibb, 2009). Children who experienced high levels of hostility from parents required less perceptual information to recognize angry expressions (Pollak et al., 2009). On the opposite, physically abused children required more information to correctly identify sad expressions (Pollak & Sinha, 2002). According to this aspect, also former child soldiers (actually young adult at the time of the study) showed difficulties in the correct identification of sadness (Umiltà et al., 2013). Even if an emotion expressed at high levels of intensity (many expressive cues) should not be an ambiguous stimulus (Gao & Mauner, 2010; Guo, 2012), these young adults that took part to Sierra Leone's civil war were facilitated by the increase of intensity in correctly labeling the expression of all emotions (joy, fear, anger), but the expression of sadness. Moreover, they displayed the tendency to over-attribute the anger label when mislabeling sadness (Umiltà et al., 2013). A specific alteration of emotion recognition processes consisting in an over-attribution of anger label to other negative facial expressions of emotions was also found in adolescents (Ardizzi et al., 2013) and children with prolonged maltreatment experiences in their early years (Ardizzi et al., 2015). This pattern of response was not related with cognitive levels and it was consistent with the hypothesis that early and prolonged maltreatment and neglect can deeply affect the development of low mechanisms involved in higher functions as perception and attention (Ardizzi et al., 2015).

A study involving children who faced a ferocious terrorist attack showed a similar dysfunctional emotion recognition pattern, that is the tendency to label mixed-emotion stimuli as anger, also after single trauma exposure (Scrimin et al., 2009). From an evolutionary perspective, this bias can lead to an adaptive behavior in an effort to survive: a higher sensitivity and a quick detection of anger signals may elicit a prompt avoidance reaction of abusing or threat-related contexts (Kim & Cicchetti, 2010; Pollak & Tolley-Schell, 2003).

Faces are biological stimuli with the great power to convey emotions, intentions and internal states, not only in humans but also among other animals, especially mammalians living in groups (Darwin, 1872; Pascalis & Kelly, 2009). The prompt and effective decoding of the ever-changing facial expressions leads to pertinent reactions and interactions with other conspecifics. Thus, the skill of facial expressions recognition can predict the effectiveness of more general social competences (Mostow et al., 2002). A successful social competence determines the efficacy of the comprehension, orientation and interaction with one's own physical and social environment. From this perspective, the bias in the recognition of angry facial expressions, if on the one hand might be adaptive as urgent reaction to aberrant and negative social environments, when exhibited rigidly and out of context it becomes, on the other, maladaptive (Rose & Abramson, 1992; Cicchetti et al., 2000; Pollak & Tolley-Schell, 2003), potentially compromising the effectiveness of social behaviors. Moreover, given that PTSD is associated with chronic patterns of re-experiencing, alterations in cognitions and moods, hyperarousal, and spatial allocation of attention to trauma-relevant information, the bias in the recognition of the facial expression of anger may contribute to the recurrence of trauma-related memories, reinforcing the persistence of negative alterations in cognition and mood, as well as symptoms like hyperarousal and intrusive recollections (Ehlers & Clark, 2000; Halligan et al., 2003; Amir et.al, 2009). Accordingly, PTSD patients with difficulties in disengaging their attention from aversive cues in emotional stroop and detection of target tasks, exhibited a decrease in disengagement bias following PTSD symptoms amelioration (El Khoury-Malhame et al., 2011).

1.2 Ebola virus disease outbreak as traumatic event

In 2014 first cases of the hemorrhagic fever known as Ebola virus disease (EVD) were reported in West Africa. At the end of the same year, Ebola fever disease turned in the form of a serious outbreak affecting Guinea Conakry, Liberia and Sierra Leone. The EVD was first discovered in 1976 but this outbreak was the hugest and the most complex Ebola outbreak that humans had ever seen (World Health Organization, 2016). The virus was originally transmitted to people from wild animals (bats, chimpanzees etc.) and then spread through human-to-human transmission via direct contact with blood, secretions, body fluids of infected people (World Health Organization, 2016). Because of poor precautions, also many health-care workers had been infected (Qureshi, 2016). Traditional burial ceremonies in which mourners usually kiss and touch the body may have contributed to spread EVD (Qureshi, 2016). The incubation period ranges from 2 to 21 days. First symptoms are fever, fatigue, muscle pain, headache and sore throat. Subsequently vomit, diarrhea and, sometimes, both internal and external bleeding can appear. The average EVD fatality rate is around 50%. Case fatality rates have varied, in past outbreaks, between 25% and 90%. From spring 2014 to spring 2016, 28.646 cases and 11.323 deaths had been recorded (World Health Organization, 2016). In particular, 14.124 cases and 3.956 deaths had been reported in Sierra Leone (World Health Organization, 2016). While past outbreaks EVD usually occurred in remote villages, differently the last one affected major urban as well as rural areas. Since the end of July 2014 when Sierre Leone declared a national state of emergency, several districts were put under isolation: Kenema, Kailahun, Port Loko, Bombali, Moyamba, Tonkolili (http://www.bbc.com/news/world-africa-29360484). After a three-day lockdown consisting in confining six million people in their houses while 28.500 community workers went door-to-door with life-saving information, also houses with identified cases were quarantined (https://www.unicef.org/media/media_75963.html). Two million people, about a third of the country's population, were in these areas of restricted travel (http://www.yorkshirepost.co.uk/news/third-of-sierra-leone-population-now-under-quarantine-over-ebola-1-6861857). During the entire duration of the outbreak, and also in the course of the following months, episodes of violence, rioting and stigmatization were reported (Street child of Sierra Leone, 2015; Qureshi, 2016).

A consistent social problem that raised from the outbreak was the presence of several underage people living in this climate of terror, panic and death in very precarious situations. Most of them lost parents, caregivers and relatives. Until February 2015, 12.023 children orphaned by Ebola were reported across the country (Street child of Sierra Leone, 2015). The 57% of the identified orphans belonged to rural regions far from psychosocial and monitoring support (Street child of Sierra Leone, 2015). The 27% had lost both parents; 32% had lost mother; 41% had lost father (Street child of Sierra Leone, 2015). The same report predicted the possibility of further 3.630 children orphaned. The report found out that the major challenges that Ebola orphans had to face were stigma from their communities; trauma associated with their loss, fear to be infected, grief and uncertainty, poverty, malnutrition and lack of access to education resulting from being left alone. On average, the age of these children was 9 years old (Street child of Sierra Leone, 2015). The orphans also faced several risks such as marginalization and neglect after rehoming, abuse, teenage pregnancy and sexual exploitation (Street child of Sierra Leone, 2015).

This overview of the recent situation of Sierra Leone leads to assert that the underage population was, and probably still is, one of the most vulnerable category across the overall population that has struggled with such a traumatic situation.

1.3 Aims of the study

To date, the bias in the recognition of angry facial expressions, consisting in the erroneous over-identification of anger when other negative facial expressions are visualized, is quite well-known. Several empirical studies investigated this phenomenon with different paradigms and involving samples of underage victims of different traumatic experiences (Pollak et al. 2000; Pollak &Sinha, 2002; Ardizzi et al., 2013; 2015; Umiltà et al., 2013; Scrimin et al., 2009). Comparing all these results, it appears that the bias in the explicit recognition of angry facial expressions is a consequence of both acute (Scrimin et al., 2009) and prolonged (Pollak et al., 2000; Pollak & Sinha, 2002; Pollak & Kistler, 2002; Pollak et al., 2009; Umiltà et al., 2013; Ardizzi et al., 2013; 2015) exposure to traumatic events during childhood. Despite this plethora of studies, to date it remains unclear whether this bias can be interpreted as an overall victims' response tendency or as an effect of a specific tuning of victims' perceptive mechanisms to angry facial expressive cues. According to the first hypothesis, when abused children are asked to match facial expressions to emotional contexts they exhibit a response bias for anger (Pollak et al., 2000). The bias for anger was interpreted by these authors as a response tendency displayed when the children are uncertain about which facial expression to select. The presence of the tendency to over-attribute the anger label to other negative emotions when incorrectly recognized, was also found in Sierra Leonean street-children with high maltreatment and neglect exposure (Ardizzi et al., 2015). Despite results showed that both experimental and control groups tended to exhibit more frequently an over-attribution of anger label compared to other possible labels, this tendency was significantly higher among street-children than controls.

Another study conducted by Pollak & Sinha (2002) proposed an alternative interpretation of the bias for anger, not based on an overall response tendency. In this study, physically abused children and controls had to recognize emotional facial expressions displayed at different degrees of resolution (i.e., from very degraded image to full resolution image). Children with a history of abuse showed a higher sensitivity to anger than controls, so they were able to recognize the emotion of anger with less sensory inputs than age-matched controls. Interestingly, they did not display an overall anger response tendency when highly degraded stimuli (high uncertainty) were visualized. This finding led the authors to hypothesize that children exposed to prolonged maltreatment and abuse were guided by specific anger expressive cues in the recognition of negative emotional facial expressions rather than by an anger response tendency. From this point of view, specific anger expressive cues may become more salient after traumatic experiences.

The hypothesis inspiring the present study is that if the bias for anger depends on the greater salience of specific anger expressive cues, similar visual exploration patterns should be detected both when victims of trauma commit a bias during the recognition of negative stimuli (fear and sadness) as well as when they correctly recognize facial expressions of anger. Facial expressions of emotions are implemented with specific configurations of facial muscle movements that provide the perceptual input useful to discriminate and decode different emotional expressions (Ekman & Friesen, 1978). Therefore, depending on the emotion expressed, some regions of the face can contain more useful information than others (Schurgin et al., 2014). Playing different roles in the expression of emotions, different face components also contribute to the regulation of social interactions (Beaudry et al., 2014). According to these ideas, correct emotion recognition is associated with characteristic patterns of fixations that reflect corresponding characteristic patterns of attention (Schurgin et al., 2014). The anger specific eye-movement strategy shows the majority of fixations applied to the eye and nose regions and the minority to the mouth region (Smith et al., 2005; Schurgin et al., 2014). The same fixation pattern on the eye region appears during the exploration of sadness expression (Eisenbarth & Alpers, 2011). The mouth-region is longer stared with happy facial expression than with sad and fearful facial expressions (Eisenbarth & Alpers, 2011). However, correct fearful expression recognition usually requires more fixation upon the mouth region than sadness (Eisenbarth & Alpers, 2011).

Another kind of dominance effect is manifested with regard to the vertical division of the face (right vs. left halves), with a dominance effect of the left-side from the observer's view, or the right-side from the actor's perspective. Since the 1960s, empirical studies highlighted that people spend more time looking to the left side of a photographed face than to the right one (Yarbus, 1967). The left-side bias has been confirmed in several studies whose results suggested that directing the initial fixations to the left side of a face predicts best face recognition (see for example Hsiao & Cottrell, 2008; Hsiao & Liu, 2012). Even if it still unclear their roles and influences, it seems that both perceptual learning and right hemisphere are involved in the left-side bias (Hsiao & Liu, 2012). Young adults with autism spectrum disorders are generally characterized by impaired face processing abilities and marked deficits in configurational processing as well as absence of the left-visual-field bias (Dundas et al., 2012).

Proceeding from the literature here described, the main aim of the present study was to investigate the low-level mechanisms of visual exploration underlying higher perceptual and attentional functions that seem to be altered among victims of childhood trauma, showing the bias in the recognition of anger facial expressions. Therefore, a sample of underage Ebola virus disease survivors and a sample of age-matched controls, both coming from Sierra Leone, were recruited. Previously, the PTSD Checklist for DSM-5 (PCL-5), the Impact of Event Scale-revised (IES-R) and the Cognitive Emotion Regulation Questionnaire short version (CERQ-short) were translated and validated, following a cross-cultural adaptation process (Beaton et al., 2000). After that, these scales were administered to both groups of participants to assess the specific effect of being exposed to Ebola outbreak. Participants took part to a forced-choice facial expressions recognition task, in which they were asked to explicitly identify 4 basic facial expressions of emotions (i.e., anger, fear, joy, sadness), choosing one of the four proposed labels. During the execution of the task, participants' eye movements were recorded by means of the eye-tracking technique.

We expected to confirm in the young Sierra Leonean traumatized population the presence of the bias for anger in the recognition of facial expressions of emotion. This result would confirm that the bias can appear not only as consequence of prolonged traumatic experiences but also as consequence of a single intense traumatic exposure, as a previous study suggested (Scrimin et al., 2009). Furthermore, significant correlations between the bias and the scores obtained in clinical scales evaluating the presence of PTSD symptomatology would not only prove the successful reliability of the cross-cultural adaptation process, but also directly link two different consequences of trauma exposure during childhood. It is important to note that this is the first time that clinical scales for the evaluation of PTSD have been translated and adapted to an African country, specifically to Sierra Leone. Finally, we expected to find characteristic visual exploration patterns, in terms of fixations number, duration and location, related with the anger over-attribution bias. This would be consistent with the hypothesis that, after trauma exposure, the recognition of facial expressions of negative emotions is led by specific anger expression cues rather than by a general anger response tendency.

Increased knowledge about how traumatic experiences can deeply alter emotional recognition skills, compromising the overall social competence and providing possible maladaptive social behaviors, can be very important for several reasons. First, it can help to understand the role of experience in the development of the complex systems involved in the recognition of others' emotional states. Therefore, the current challenge is to understand how, when, in which measure and why some intense negative experiences can divert the developmental course of this system, partly determined by genetic inheritance (Sroufe 1979; Herba & Phillips, 2004). Finally, to understand the mutual influence of phylogenetic and ontogenetic factors is not just a matter of pure knowledge, it can also be essential in the effort to prevent and treat psychopathologic drifts occurring after trauma exposure.

2. MATERIAL AND METHODS

2.1 Participants

Sixty-one underage Sierra Leonean participants were recruited for the study. Of these 30 were Ebola virus disease (EVD) survivors (Survivor group: mean age 15.53 years, SE=0.36; years of schooling 8.8 years, SE=0.46; 14 males) and 31 were controls (Control group: mean age 14.55, SE=0.30; years of schooling 8.07 years, SE=0.30, 15 males). The sample size exceeded the minimum amount required (n. 56) 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). The sampling was suspended when two sex-balanced groups of enough size were obtained.

Participation in the study was completely voluntary, no participant has been paid. Participants were recruited with the support of non-profit organizations (RCRC and FHM-Italia Onlus) working with Sierra Leonean youths. Survivor group' participants came from Freetown East area that was the most affected by EVD. They were selected on the basis of medical records describing the date of Ebola infection, received medical treatments and recovery date. On average, EVD infection lasted 22.7 days (SE=3.39) and was contracted 230 (SE=19.51) days before the execution of the study. All Survivor group's participants were hospitalized for an average period of 296.9 days (SE=27.13) and lost, on average, 4.6 (SE=0.71) family members as a consequence of EVD.

Control group participants were recruited among people from Freetown but resettled in neighboring villages monitored by checkpoints during the Ebola outbreak. As a consequence of this practice for infection prevention and control, none of Control group's participants contracted EVD and lost family members.

Study general purposes and procedures were explained by local social-workers to volunteers and their legal guardians. After participants' agreement in study involvement, a written informed consent was collected. Participants' demographic data (i.e., sex, age, weight, height, dominant hand, level and years of schooling, first and second language, ethnic group) and medical and pharmacological information about actual and past health conditions (i.e., disease duration, sanitary treatments, hospitalization, family members infected and deceased) were collected. Furthermore, self-perceived risk (P.R) and comparative perceived risk (P.C.R) about common infective and metabolic diseases were assessed among participants. Participants were asked to evaluate the probability to contract different illnesses both in the next 12 months (P.R.) and with respect to western age and sex matched people (P.C.R). Lastly, data about participants' socio-economic status (i.e., family unit, members of household, occupation) and critical life events (i.e., sexual violence, physical violence, abuse, maltreatment) were gathered. Partial or unclear information was completed and checked thanks to sanitary, educational or charitable institutions.

To exclude the presence of visual deficits, participants' visual acuity (20/20) was estimated following standard procedure by means of Snellen chart (Snellen, 1862). Moreover, kinetic visual field test and pupillary light responses (i.e., direct and consensual light reflexes) were assessed in all participants.

In order to evaluate participants' cognitive performance and naming skills, Standard Progressive Matrices test (SPM, Raven et al., 1998) and Boston naming test (BNT; Kaplan et al., 1983) were administered. No significant differences were found between the two groups for BNT (Survivor group: 21.70, SE=1.05; Control group: 22.97, SE=0.93; $t_{59} = -0.90$, $p = 0.37$) and SPM scores (Survivor group: 75.74, SE = 2.81; Control group: 72.62, SE = 1.04; $t_{46} = 1.20$, $p = 0.24$).

Moreover, three clinical scales commonly used to evaluate the psychological impact of negative events and the presence of symptoms of post-traumatic stress disorders were translated from English to Krio and validated on a Sierra Leonean sample. The PTSD Checklist for DSM-5 (PCL-5, Weathers et al., 2013) is a 20-item self-report measure that assesses the 20 DSM-V symptoms of PTSD. The Impact of Event Scale-revised (IES-R, Weiss and Marmar, 1996) is a 22-item self-report measure that assesses subjective distress caused by traumatic events. Items correspond directly to 14 DSM-IV symptoms of PTSD. Respondents were asked to identify a specific stressful life event and then indicate how much they were distressed or bothered during the past seven days by each "difficulty" listed. To the purposes of the present study, all participants were asked to answer questions considering Ebola outbreak as the stressful life event. The Cognitive Emotion Regulation Questionnaire short version (CERQ-short, Garnefski and Kraaij, 2006) is a 18-item self-report scale evaluating the role played by victims' emotion regulation in adaptation to stressful life events. The Guidelines for the Process of Cross-Cultural Adaptation of Self-Report Measures (Beaton et al., 2000) were followed for the translation of the described scales. To validate the translated scales, a sample of 40 Sierra Leonean underage volunteers of both sexes not included in the experimental samples, filled the scales. The obtained scores demonstrated that the translated scales were correctly understood and applicable to Sierra Leonean population. Interestingly, the Survivor group's total score obtained with the PCL-5 (Survivor group: 30.43, SE=2.01; Control group: 16.55, SE=2.40; t_{59}= 4.42, p = 0.00) and the IES-R scales (Survivor group: 1.63, SE=0.09; Control group: 0.65, SE=0.14; t_{59} = 5.68, p = 0.00) resulted significantly higher with respect to the Control group's score. See Table 1 for mean scores and significant differences between the two groups with the PCL-5, IES-R and CERQ-short subscales.

Table 1 – Questionnaire scores of Ebola Virus Disease Survivors (Survivor group) and Controls (Control group). Significant between-groups differences were estimated. * = $p < 0.05$; ** = Bonferroni corrected $p < 0.016$; *** = Bonferroni corrected $p < 0.012$; **** = Bonferroni corrected $p < 0.005$. P.R.= Self-perceived Risk; C.P.R.= Comparative Perceived Risk; BNT= Boston Naming Test; SPM= Standard Progressive Matrices test; IES= Impact of Event Scale-revised; PCL-5= PTSD Checklist for DSM-5; CERQ= Cognitive Emotion Regulation Questionnaire short version.

Scales	**Subscales**	**Survivors**	**Controls**	**Between-groups Differences**
N. Tot		30	31	/
N. males		14	15	/
P.R.		1.43; SE 0.078	1.35; SE 0.031	t_{59}=1; p=0.320
C.P.R.		4.19; SE 0.11	4.15; SE 0.061	t_{59}=0.37; p=0.712
BNT		21.70; SE 1.05	22.97; SE 0.93	t_{59}=-0.90; p= 0.370
SPM		75.74; SE 2.81	72.62; SE 1.04	t_{46}=-1.20; p= 0.240
IES_TOT*		1.63; SE 0.09	0.65; SE 0.14	t_{59}=5.68; p= 0.000
	Intrusion**	1.50; SE 0.10	0.58; SE 0.13	t_{59}= 5.49; p=0.000
	Avoidance**	1.89; SE 0.10	0.74; SE 0.16	t_{59}=5.97; p= 0.000
	Hyperarousal**	1.44; SE 0.12	0.63; SE 0.16	t_{59}=4.02; p=0.000
PCL5_TOT*		30.43; SE 2.01	16.55; SE 2.40	t_{59}=4.42; p=0.000
	Cluster B***	9.07; SE 0.80	4.55; SE 0.75	t_{59}=4.13; p=0.000
	Cluster C***	3.37; SE 0.32	1.58; SE 0.38	t_{59}=3.61; p= 0.001
	Cluster D***	9.97; SE 0.91	5.90; SE 0.90	t_{59}=3.17; p=0.002
	Cluster E***	8.03; SE 0.82	4.52; SE 0.72	t_{59}=3.24; p=0.002
CERQ				
	Self-Blame	2.53; SE 0.15	3.42; SE 0.31	t_{59}=-2.52; p=0.014
	Acceptance	4.37; SE 0.26	4.00; SE 0.38	t_{59}=0.79; p=0.43
	Rumination****	5.90; SE 0.35	4.13; SE 0.36	t_{59}= 3.52; p=0.001
	Positive Refocusing	6.63; SE 0.31	5.13; SE 0.47	t_{59}= 2.65; p=0.01
	Refocus on planning****	7.90; SE 0.25	4.58; SE 0.40	t_{59}=6.97; p=0.000

Positive reappraisal****	7.20; SE 0.33	5.16 SE 0.46	t_{59}=3.61; p=0.001
Putting in to perspective	5.30; SE 0.33	4.45; SE 0.41	t_{59}=1.60; p=0.116
Catastrophing****	7.50; SE 0.24	4.32 SE 0.44	t_{59}=6.25; p=0.000
Other blame	3.00; SE 0.33	3.29; SE 0.28	t_{59}=-0.68; p=0.502

2.2 Procedure

The entire experimental procedure was composed by two phases. The pre-experimental phase was carried out in order to translate and validate the scales used to evaluate the presence of PTSD symptoms (PCL-5, CERQ-short, IES-R). The experimental phase consisted of a forced-choice facial recognition task during which participants' visual exploration patterns of emotional facial expressions were recorded.

2.2.1 Pre-experimental phase

The three clinical scales (PCL-5, Weathers et al., 2013; IES-R, Weiss and Marmar, 1996; CERQ-short, Garnefski and Kraaij, 2006) used in this study were originally created to identify the psychological impact of traumatic events and the related symptoms in a western population. Given the different context in which this study was settled, a cross cultural adaptation was necessary to ensure the internal validity of this research. In accordance with the Guidelines for the Process of Cross-Cultural Adaptation of Self-Report Measures (Beaton et al., 2000) this process provides not only an accurate translation from the original language to the local language but it also assesses the cultural and a social relevance of the translated scales according to the target population. The cross-cultural adaption procedure was implemented on questionnaires instructions, the item contents and option responses. The process encompasses the 4 stages explained below (see Figure 1).

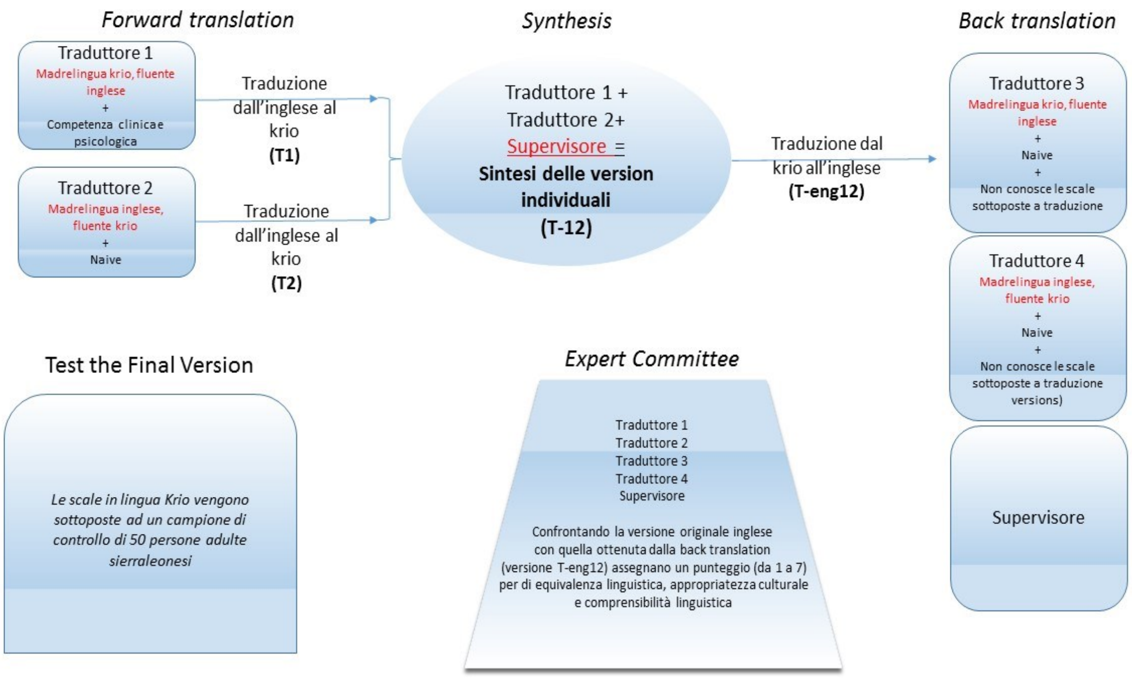

Figure 1. - Graphic representation of the cross-cultural adaptation process used in this study (adapted from Beaton et al., 2000)

Stage I: Initial translation

The first step consisted in two forward translations (T1, T2) from the source language (English) into the target language (Krio). The two independent translations were performed by two bilingual translators whose native tongue was Krio and who were fluent English. Their background was different: one translator had a medical-clinic profile and was aware about the concepts examined in the questionnaires. The other one was language expert but not informed about the aims of the questionnaires. The purpose was that the first translator could assess reliability of the clinical contents, while the second one could better assess the reliability with respect to local language.

Stage II: Synthesis of the translations

The two English to Krio translations were then summarized in one version of the translation (T12). The items that better adhered to the English version were chosen. The final version was drafted by the previous team in spoken Krio by using English alphabet instead of Krio alphabet.

Stage III: Back translation

From the T12 version, two back-translations (T3, T4) were obtained by two independent translators whose native-tongue was English and who were fluent in Krio. They also were totally blind to the original version and to the concepts explored by the scales. Neither had medical or psychological background. This stage of the cross-cultural adaptation process can highlight gross inconsistencies, erroneous interpretations and unexpected meanings in the target version of the questionnaires.

All these stages were held in the presence of local assistant and supervisor.

Stage IV: Expert Committee and final version

The committee encompasses all the members involved in the forward and back translation. Its aim was to validate and ensure the very cross-cultural equivalence of the translated versions of the scales. For each item its semantic equivalence, cultural suitability and linguistic intelligibility was evaluated with a scale from 1 to 7. The items receiving a score below 7 were discussed and collegially changed.

Finally, the committee sentenced that the T12 version was "easy to understand and appropriate to the Sierra Leonean cultural context".

2.2.2 Experimental phase

2.2.2.1 Stimuli

64 video-morphing were used as stimuli (see Figure 2). They were obtained from the Montreal Facial Displays of Emotion stimulus set (MSFDE). Each video-morphing lasted 3000 msec and showed the transition from a neutral facial expression to an emotional one (16 anger, 16 fear, 16 joy, 16 sadness). In order to exclude a possible influence of typical ethnic and gender features, 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 Tobii Studio Software.

Figure 2. Stimuli and visual scan patterns of the two groups. Panels A and B display an exemplificative frame of the video-morphing employed as stimulus and related visual exploration pattern captured by the eye-tracker of Survivor group (Panel A) and Control group (Panel B).

2.2.2.2 Experimental phase Procedure

The experimental phase took place at RCRC Center, Lakka (Freetown, Sierra Leone). For the implementation of this study the Center offered two rooms with an autonomous electrical system, which were used for the questionnaire administration and the experimental phase, respectively. During the entire duration of the experimental phase (approximately one month), five local social workers were available in order to guarantee participants' comfort, good comprehension of instructions and prompt translation from English to Krio when necessary.

Previously, biographical data, medical and pharmacological history were collected. An evaluation of the cognitive level and naming skills of all participants was obtained with Colored Progressive Matrices (CPM) and Boston Naming Test (BNT). Furthermore, an evaluation of PTSD symptoms was obtained with PCL-5, IES-R, CERQ-short administration. These scales were translated and adapted in the pre-experimental phase. Finally, participants were submitted to a rigorous exam of their visual abilities (i.e., visual field exam, acuity tests and pupillary reflexes).

For the execution of the forced-choice facial expressions recognition task, participants were comfortably sat at a desk in a quiet and soft illuminated room. They were asked to put their chin upon the chin rest in order to reduce head movements and to ensure a fixed orientation and distance of their head from the monitor. Participants were instructed to pay attention and observe each stimulus for its entire duration, identify adults' facial expressions of emotions choosing one of the four proposed labels (i.e., anger, fear, joy, sadness). Each experimental trial started with the presentation of a fixation cross, lasting for 1000 msec and placed on the left side (50% of trials) or on the right side (50% of trial) to the display center. By balancing the fixation cross lateralization, we prevented a location-related bias of the first fixations. After the disappearance of the cross fixation, all participants could freely explore the stimulus presented for 3000 msec. Each stimulus was displayed once (64 total trials, 16 trials for each of the four emotions) in random order. The response phase had no time limits. The presentation of the subsequent stimulus was determined by the researcher immediately after participants' facial expressions recognition.

2.2.3 Apparatus

The experimental phase was conducted by means of the eye-tracker study Tobii Pro X2-30 and the relative Tobii Studio Software. Tobii X2-30 was designed to capture data at 30 Hz in order to show gaze points and fixations duration. For the binocular vision, Tobii X2-30 features can be described as: gaze accuracy (angular average distance from the actual gaze point to the one detected by the eye tracker) close to 0.5-0.7 degrees; gaze precision (spatial variation between individual gaze samples) 0.32 degrees; latency (time between the acquisition of eye's position and start of data recording) less than 35 msec.

The Software Tobii Studio allows to design the so-called Areas of Interest (AOIs) in order to analyze the visual exploration just in specific regions of the stimuli. For this study four AOIs were created: eye- left, eye-right, mouth, nose (stimulus-related) (see Figure 3).

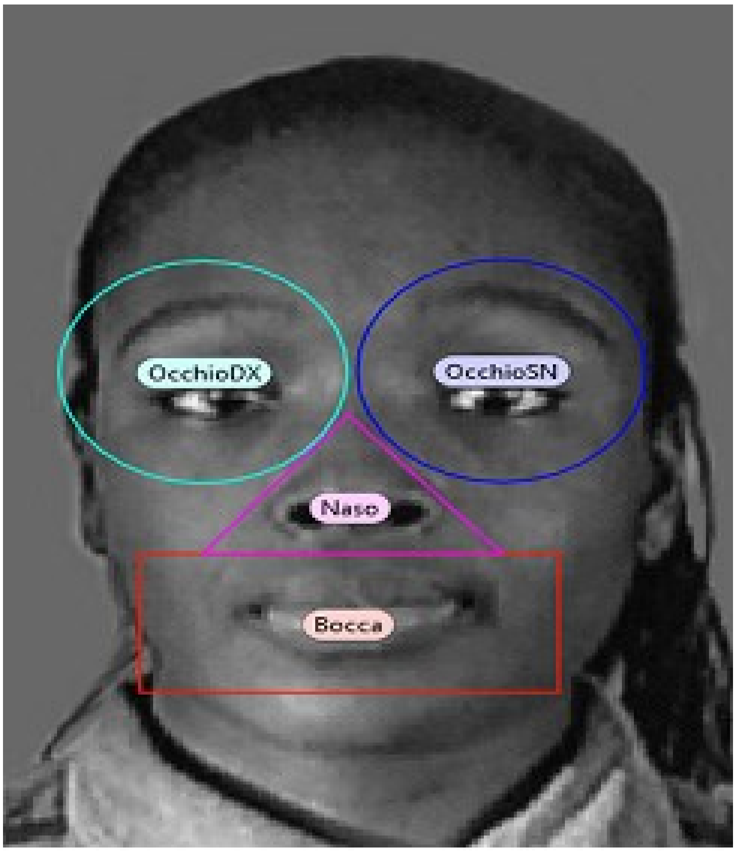

Figure 3. Areas of Interest (AOIs). Exemplificative movie-AOIs adopted in the present study. Eye-left and eye-right AOI (123x121 pixels), nose AOI (149x98 pixels), mouth AOI (190x84 pixels).

The eye AOIs (123x121 pixels) included eye, eyelids, eyebrows and part of the upper nose; the nose AOIs (149x98 pixels) included nostrils, columela, rhinion; the mouth AOIs (190x84 pixels) included all the mouth from philtrum to the upper part of the chin. Due to the nature of the stimuli employed in the present study, these areas of interest were created as moving AOIs because they fit, maintaining the same size, to the natural movement of the anatomical areas producing emotional expressions during the videos. Moreover, the Software Tobii Studio reveals if a fixation stands in AOIs, their duration and their chronological sequence.

In order to assess a fixation, the "I-VT fixation" filter was used, based on an algorithm able to calculate whether the raw eye movement data, identified with a timestamp and "X,Y" coordinates, belong to the same fixation. The general idea behind the I-VT filter is to classify eye movements based on the velocity of the directional shifts of the eye. If the velocity of the eye movement is below a certain threshold the samples are identified as part of a fixation (http://acuity-ets.com/downloads/Tobii%20I-VT%20Fixation%20Filter.pdf)

3. RESULTS

3.1. Behavioral Statistical Analyses

Possible differences between-groups in participants' recognition of facial expressions of emotions were investigated by repeated-measures ANOVA conducted on participants' accuracy rate. Accuracy rates for each emotion were computed as the percentage of correct identification on the total number of participants' response per emotion. Participants' Group (Survivor; Control) was entered as between factor, whereas Emotion (anger, fear, joy, sadness) was entered as within factor.

Possible between-groups differences in participants' recognition bias for angry facial expressions were investigated by means of repeated-measures ANOVA conducted on participants' bias rate. According to previous studies (Ardizzi et al., 2013; 2015), when participants are involved in a forced-choice facial expressions recognition judgment, as the one here required, the bias for the recognition of angry facial expressions can be described as the erroneous tendency to over-attribute the anger label to other negative emotions. Indeed, bias rates for the facial expressions of fear and sadness were computed as the percentage of mistaken use of the anger label on the total number of errors committed during the identification of the facial expressions of fear and sadness, respectively. Participants' Group (Survivor; Control) was entered as between factor, whereas Emotion (fear, sadness) was entered as within factor.

All percentages were subjected to variance-stabilizing procedure for a binomial proportion through arcsin-square-root transformation. When the sphericity assumption was violated, Greenhouse-Geisser–correction was calculated and adjusted degrees of freedom (df), corrected p values, and epsilon values (Ɛ) reported. Whenever appropriate, significant differences between- and within-group were explored performing Sidak post-hoc comparisons. Partial eta square ($\eta 2p$) was calculated as effect size measure.

In order to evaluate if the recognition bias for angry facial expression was linearly related to traumatic experiences assessed by means of the Impact of Event Scale (IES) and the PTSD Checklist for DSM-5 (PCL5), 4 skipped Pearson correlations were performed between participants' bias rate for sadness and fear facial expressions and participants' score at IES and PCL5 scales. Bootstrap confident interval (bCI) were reported and the p_s were corrected for multiple comparisons ($p < 0.0125$).

3.2 Total Eye-tracking Statistical Analyses

Total Fixation analyses of correct facial expression identification

Possible between-groups differences in participants' fixation number was investigated by repeated-measures ANOVA conducted on participants' mean fixation number performed during correct identification of emotion. The mean fixation number for each emotion was computed as the total number of fixation on the total number of participants' correct responses per emotion. Participants' Group (Survivor; Control) was entered as between factor, whereas Emotion (anger, fear, joy, sadness) was entered as within factor.

Possible between-groups differences in participants' fixation duration was investigated by repeated-measures ANOVA conducted on participants' mean fixation duration performed during correct identification of emotion. The mean fixation duration for each emotion was computed as the total duration of fixations on the total number of participants' correct responses per emotion. Participants' Group (Survivor; Control) was entered as between factor, whereas Emotion (anger, fear, joy, sadness) was entered as within factor.

Total Fixation analyses of biased facial expression identification

Possible between-groups differences in participants' fixation number was investigated by repeated-measures ANOVA conducted on participants' mean fixation number performed when participant committed a bias in the recognition of negative facial expressions of emotions. The mean fixation number for each emotion was computed as the total number of fixations on the total number of participants' biased responses per emotion. Participants' Group (Survivor; Control) was entered as between factors, whereas Emotion (fear, sadness) was entered as within factor.

Possible between-groups differences in participants' fixation duration was investigated by repeated-measures ANOVA conducted on participants' mean fixation duration performed when participants committed a bias in the recognition of negative facial expressions of emotions. The mean fixation duration for each emotion was computed as the total duration of fixation on the total number of participants' biased responses per emotion. Participants' Group (Survivor; Control) was entered as between factors, whereas Emotion (fear, sadness) was entered as within factor.

Total fixation analyses comparing accurate and biased identification

In order to compare groups' performances on the total number of mean fixations performed during an accurate and biased facial expressions of emotions recognition, repeated-measures

ANOVAs were conducted on participants' accurate and biased mean fixation number, independently for the facial expressions of sadness and fear. In both cases, participants' Group (Survivor; Control) was entered as between factors, whereas Accuracy (Accuracy, Bias) was entered as within factor.

In order to compare groups' performances on the mean duration of fixations performed during an accurate and biased facial expressions of emotions recognition, repeated-measures ANOVAs were conducted on participants' accurate and biased mean fixation duration, independently for the facial expressions of sadness and fear. In both cases, participants' Group (Survivor; Control) was entered as between factors, whereas Accuracy (Accuracy, Bias) was entered as within factor.

3.3 AOIs Eye-tracking Statistical Analyses

AOIs Fixation analyses of correct facial expression identification

Possible between-groups differences in participants' fixation percentage number was investigated by repeated-measures ANOVA conducted on participants' fixation percentage number performed during correct identification of emotions. The fixation percentage of each AOI for each facial expression of emotion was computed as the percentage of fixation in each AOIs on the total number of participants' fixations. Participants' Group (Survivor; Control) was entered as between factor, whereas Emotion (anger, fear, joy, sadness) and AOIs (eye-left, eye-right, mouth, nose) were entered as within factors.

Possible between-groups differences in participants' fixation percentage duration was investigated by repeated-measures ANOVA conducted on participants' fixation percentage performed during the correct identification of emotions. The fixation percentage of each AOI for each facial expression of emotion was computed as the percentage of fixation duration in each AOIs on the total duration of participants' fixations. Participants' Group (Survivor; Control) was entered as between factor, whereas Emotion (anger, fear, joy, sadness) and AOIs (eye-left, eye-right, mouth, nose) were entered as within factors.

AOIs Fixation analyses of biased facial expression identification

Possible between-groups differences in participants' fixation percentage number was investigated by repeated-measures ANOVA conducted on participants' fixation percentage performed during biased identification of emotions. The fixation percentage of each AOI for each facial expression of emotion was computed as the percentage of fixation in each AOIs on the total number of participants' fixations. Participants' Group (Survivor; Control) was entered as between factor, whereas Emotion (fear, sadness) and AOIs (eye-left, eye-right, mouth, nose) were entered as within factors.

Possible between-groups differences in participants' fixation percentage duration was investigated by repeated-measures ANOVA conducted on participants' fixation percentage performed during biased identification of emotions. The fixation percentage of each AOI for each facial expression of emotion was computed as the percentage of fixation duration in each AOIs on the total duration of participants' fixations. Participants' Group (Survivor; Control) was entered as between factor, whereas Emotion (fear, sadness) and AOIs (eye-left, eye-right, mouth, nose) were entered as within factors.

AOIs fixation analyses comparing accurate and biased identification

In order to compare groups' performance on the percentage number of fixation performed during an accurate and biased recognition of facial expressions of emotions, repeated-measures ANOVAs were conducted on participants' accurate and biased percentage number fixation, independently for the facial expressions of sadness and fear. In both cases, participants' Group (Survivor; Control) was entered as between factors, whereas Accuracy (Accuracy, Bias) and AOIs (eye-left, eye-right, mouth, nose) were entered as within factors.

In order to compare groups' performance on the percentage duration of fixation performed during an accurate and biased recognition of facial expressions of emotions, repeated-measures ANOVAs were conducted on participants' accurate and biased percentage fixation duration, independently for the facial expressions of sadness and fear. In both cases, participants' Group (Survivor; Control) was entered as between factors, whereas Accuracy (Accuracy, Bias) and AOIs (eye-left, eye-right, mouth, nose) were entered as within factors.

3.4 Behavioral results

Accuracy rate

Mauchly's test conducted on participants' accuracy rate showed a violation of sphericity assumption for Emotion factor ($\chi^2_{(5)} = 27.220$, $p < 0.001$). Hence, degrees of freedom were adjusted using Greenhouse-Geisser correction ($\varepsilon = 0.76$). Repeated-measures ANOVA revealed a significant main effect of the factors Group ($F_{1,56} = 4.288$, $p = 0.043$; $\eta^2_p = 0.071$) and Emotion ($F_{2.28,56} = 117.182$, $p < 0.001$; $\eta^2_p = 0.677$) and a significant interaction Emotion by Group ($F_{2.28,56} = 4.430$, $p = 0.011$; $\eta^2_p = 0.073$).

Post-hoc comparison conducted on the main effect of Group revealed that Survivor group (1,173 rad accuracy, SE=0.023) showed a significantly higher accuracy rate than Control group (1.106 rad accuracy, SE=0.022).

Post-hoc tests conducted on the main effect of Emotion revealed, as expected, that joy facial expression was the most correctly identified (1,510 rad accuracy, SE=0.016; all $p_s < 0.001$), whereas sadness facial expression was the worst recognized emotion (0,819 rad accuracy, SE=0.025; all $p_s < 0.001$). No significant difference was estimated between the recognition of the facial expressions of anger (1.134 rad accuracy, SE 0.023) and fear (1.096 rad accuracy, SE 0.041; $p = 0.941$).

Post-hoc tests performed on the interaction Emotion by Group showed that Survivor group had a significantly greater emotion recognition performance than Control group when judging the facial expressions of anger (Survivor group: 1.206 rad accuracy, SE 0.034; Control group: 1.062 rad accuracy, SE 0.032; $p = 0.003$) and fear (Survivor group: 1.182 rad accuracy, SE 0.059; Control group: 1.010 rad accuracy, SE 0.057; $p = 0.042$).

Bias rate

Repeated-measures ANOVA revealed a significant main effect of the factors Group ($F_{1,56}= 4.667$, $p = 0.035$; $\eta^2_p = 0.077$) and Emotion ($F_{1,56}= 32.265$, $p < 0.001$; $\eta^2_p= 0.366$).

Post-hoc comparison conducted on the main effect of Group revealed that Survivor group (0.818 rad bias, SE 0.052) showed a significantly higher bias rate than Control group (0.661 rad bias, SE 0.050) (see figure 4).

Post-hoc test conducted on the main effect of Emotion revealed that all participants showed higher recognition bias for angry facial expression when judging the facial expressions of sadness (0.933 rad bias, SE 0.041) than the facial expressions of fear (0.546 rad bias, SE 0.057).

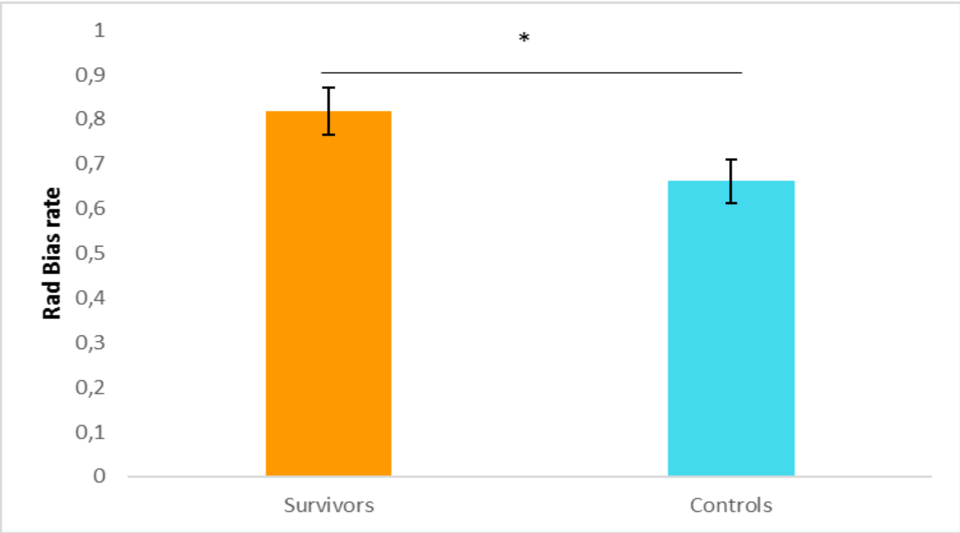

Figure 4. Rad Bias rate. Between groups difference in Bias rate. *= $p < 0.05$; error bars depicted SE.

Correlation analyses between recognition bias for angry facial expression and clinical evaluation of PTSD

Skipped Pearson correlation between participants' bias rate for sadness facial expressions and IES score resulted significant (r_{58}= 0.335; p = 0.009; bootstrap CI 0.13 0.51) (see Figure 5). Conversely, Skipped Pearson correlation between participants' bias rate for sadness facial expressions and PCL-5 score (r_{58}= 0.271; p = 0.036; bootstrap CI 0.075 0.451) resulted not resistant to multiple comparisons Bonferroni corrected.

Considering participants' bias rate for fear facial expressions, neither the skipped Pearson correlation with IES score (r_{58}= 0.117; p = 0.373; bootstrap CI -0.115 0.351) nor the skipped Pearson correlation with PCL-5 score resulted significant (r_{58}= 0.011; p = 0.933; bootstrap CI -0.269 0.244).

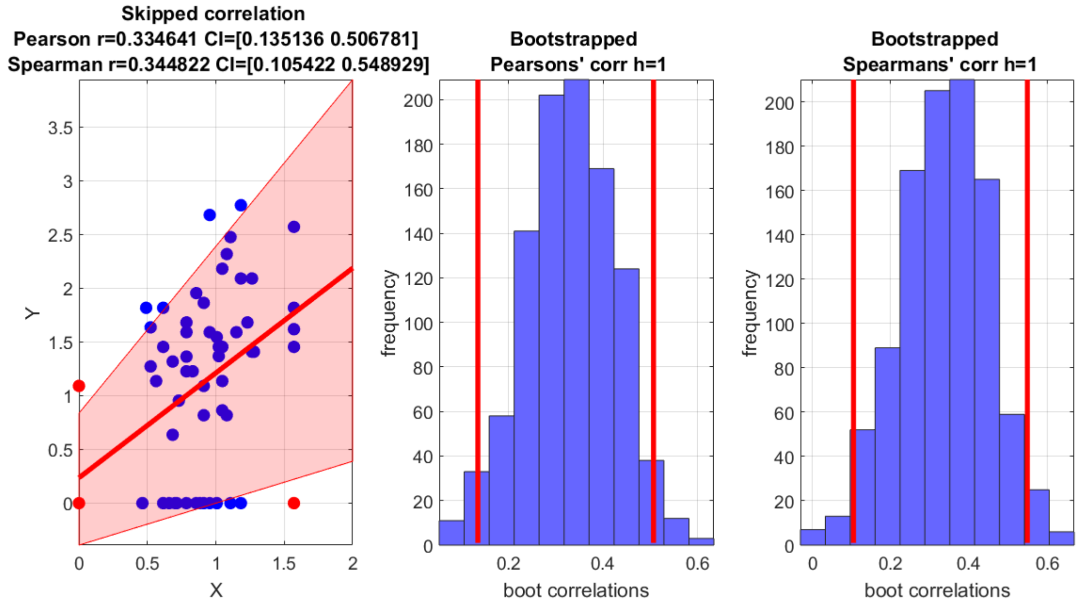

Figure 5. Skipped Pearson correlation between participants' bias rate for sadness and IES score.

3.5 Total Eye-tracking Results

Total Fixation analyses of correct facial expression identification

Repeated-measures ANOVA performed on mean fixation number revealed a significant main effect of the factor Emotion ($F_{3.171}$= 4.636, p = 0.004; η^2_p = 0.075). Sidak post-hoc comparison conducted on the main effect of Emotion revealed that the number of fixations performed on the facial expression of joy (8.117 n. fixation, SE=0.197) was significantly lower with respect to the number of fixations performed on on the facial expression of fear (8.511 n. fixation, SE=0.172) and sadness (8.556 n. fixation, SE=0.187) (all $p_s < 0.036$).

Mauchly's test conducted on participants' mean fixation duration showed a violation of sphericity assumption for Emotion factor ($\chi^2_{(5)}$ = 11.369, p < 0.045). Hence, degrees of freedom were adjusted using Greenhouse-Geisser correction (Ɛ = 0.883). Repeated-measures

ANOVA performed on mean fixation duration revealed an absence of significant main effects and interaction.

Total Fixation analyses of biased facial expression identification

Repeated-measures ANOVA performed on mean fixation number revealed an absence of significant main effects and interaction.

Repeated-measures ANOVA performed on mean fixation duration revealed an absence of significant main effects but a significant interaction Emotion by Group ($F_{1.32}$= 4.822, p = 0.035; η^2_p = 0.131). Sidak post-hoc comparison conducted on the interaction Emotion by Group revealed significantly longer fixations performed on the facial expression of fear (324.873 msec, SE=29.540) with respect to the facial expression of sadness (269.012 msec, SE=29.171), only among control participants (p = 0.019).

Total fixation analyses comparing accurate and biased identification

Repeated-measures ANOVA comparing accurate and biased mean fixation number during the identification of the facial expression of fear revealed the absence of any significant main effect and interaction.

Repeated-measures ANOVA comparing accurate and biased mean fixation number during the identification of the facial expression of sadness revealed the absence of any significant main effect and interaction.

Repeated-measures ANOVA comparing accurate and biased mean fixation duration during the identification of on the facial expression of fear facial expression of emotion revealed the absence of any significant main effect and interaction. Repeated-measures ANOVA comparing accurate and biased mean fixation duration during the identification of the facial expression of sadness revealed the absence of any significant main effect and interaction.

3.6 AOIs Eye-tracking Results

AOIs Fixation analyses of correct facial expression identification

Mauchly's test conducted on participants' percentage of fixation number showed a violation of sphericity assumption for AOIs factor ($\chi^2_{(5)}$ = 25.234, p = 0.000) and Emotion by AOIs interaction ($\chi^2_{(44)}$ = 63.901, p = 0.027). Hence, degrees of freedom were adjusted using Greenhouse-Geisser correction (AOIs ε = 0.750; Emotion by AOIs ε = 0.793). Repeated-measures ANOVA performed on percentage of fixation revealed a significant main effect of AOIs ($F_{2.249,125.933}$= 25.935, p = 0.000; η^2_p = 0.317) as well as significant interaction AOIs by Group ($F_{3,168}$= 3.433, p = 0.018; η^2_p = 0.058) and Emotion by AOIs ($F_{7.141,125.933}$= 57.206, p = 0.000; η^2_p = 0.505).

Sidak post-hoc comparisons conducted on the main effect of AOIs showed that mouth AOI received the highest percentage of fixations, resulting significantly different from all other AOIs. No significant difference was estimated between right and left eye AOIs (eye-right: 10.698% SE=1.399; eye-left: 15.531%, SE=1.717; mouth: 33.202%, SE=2.129; nose: 21.013% SE=1.289; all p_s < 0.000).

Sidak post-hoc comparisons conducted on the interaction AOIs by Group (see Figure 6) showed that survivor participants performed a significantly greater percentage of fixations on eye-left AOIs with respect to controls (Survivor group: 19.517%, SE=2.428; Control group: 11.546%, SE=2.428; p= 0.024). On the opposite, controls showed greater percentage of fixations on mouth AOIs than survivors (Survivor group: 28.693 %, SE=3.011; Control group: 37.711 %, SE=3.011; p < 0.039). Furthermore, considering the Survivor group, the eye-right AOI was the one receiving the lowest percentage of fixations with a significant difference with eye-left AOI (eye-right:10.879 %, SE=1.979; eye-left:19.517 %, SE=2.428; p= 0.046). Finally, among controls, the eye-right AOI was the less observed one, with no significant difference with the eye-left AOI (eye-right:10.517 %, SE=1.979; eye-left:11.546 %, SE=2.428; p = 1.00).

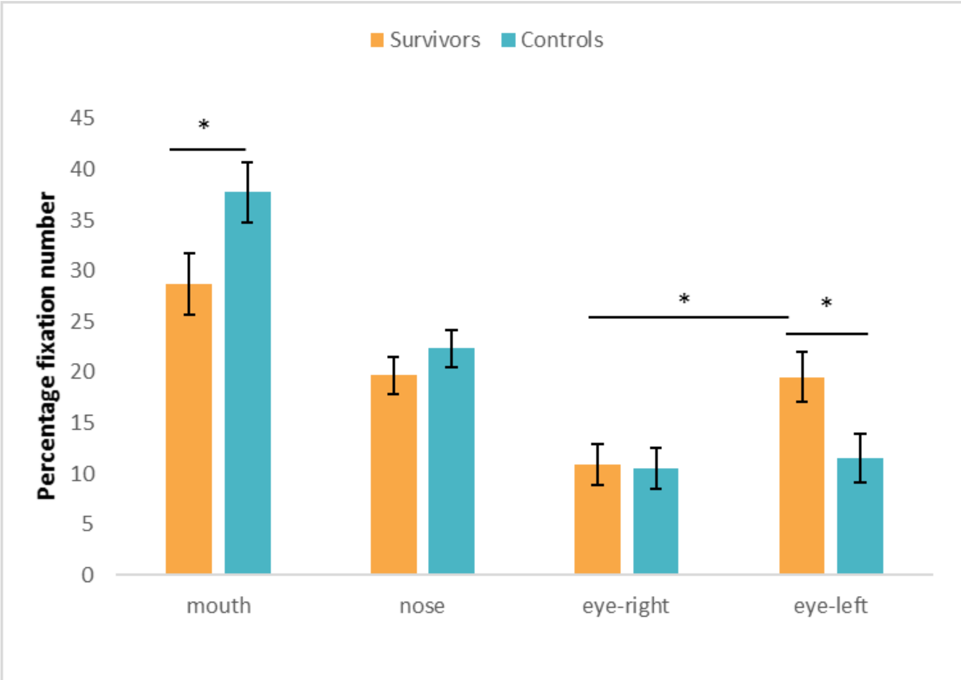

Figure 6. Percentage of fixation number during accurate recognition of emotions. Percentage of fixation number, between Survivor group and Control group, in correct identification of facial expression of emotions displayed for each AOI. * = $p < 0.05$; error bars depicted SE. See the text for all differences within groups.

Sidak post-hoc comparisons conducted on the interaction Emotion by AOIs showed that mouth AOI received a significant higher percentage of fixations during the identification of the facial expression of joy compared to all other emotional facial expressions (45.61%, SE 2.241; all ps < 0.0001). Eye-right AOI and eye-left AOI were observed with a significant different percentage of fixation, only during the proper identification of the facial expression of anger and not in the other correct recognition of facial expressions of emotions (eye-right: 10.27%, SE=1.38; eye-left: 18.29%, SE=1.994; p= 0.01).

Sidak post-hoc comparisons conducted on the main effect of AOIs factor revealed that eye-right AOI was the one observed for less time, whereas the mouth AOI was the one observed for longer time but whit no significant difference from eye-left AOI (eye-right: 14.159%, SE=0.745; eye-left: 19.898%, SE=0.865; mouth: 21.922%, SE=0.792; nose: 18.833%, SE=0.568; all $p_s < 0.007$). Sidak post-hoc comparisons conducted on the significant interaction AOIs by Group (see Figure 7) demonstrated that Survivor participants looked at eye-left AOI for significantly longer time than Control participants (Survivor group: 21.851% SE 1.224; Control group: 17.945% SE 1.224, p = 0.028). Furthermore, considering Survivor group the eye-right AOI received less fixation percentage with respect to all other AOIs (all $p_s < 0.003$). Differently, considering only the Control group, whereas no significant difference was found between eye-left and eye-right for the duration percentage (p = 0.331), mouth was the AOI receiving longer fixation than nose and eye-right AOIs (all $p_s < 0.015$).

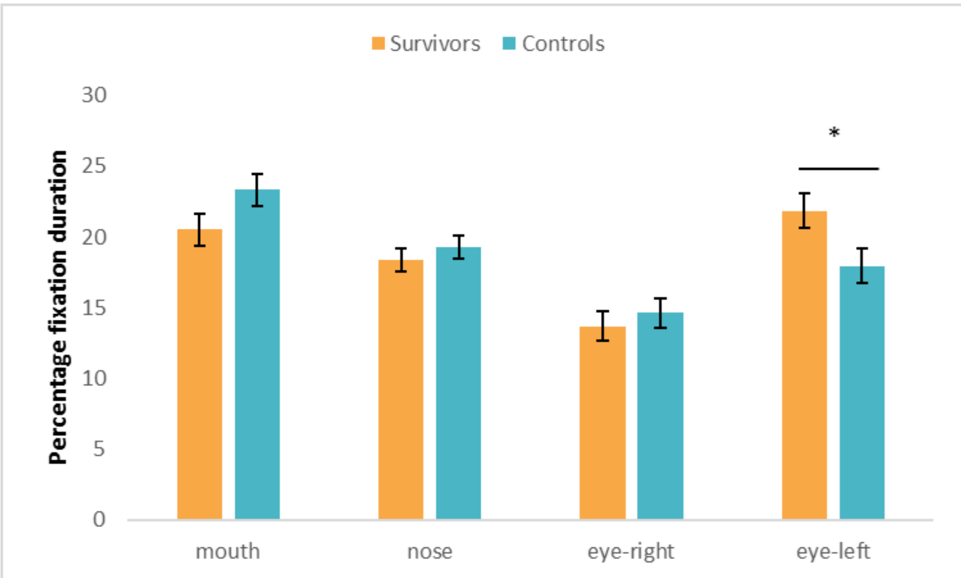

Figure 7. Percentage of fixation duration during accurate recognition of emotions. Percentage of fixation duration between Survivor group and Control group, during correct identification of facial

expression of emotions displayed for each AOI. * = $p < 0.05$; error bars depict SE. For within groups difference, see text.

Sidak post-hoc comparison conducted on the significant interaction Emotion by AOIs showed that eye-right AOI was the one observed for shortest time, especially during the observation of the facial expressions of anger and joy, where it resulted significantly different from all other AOIs (all $p_s < 0.002$). In the case of fear facial expression, eye-right AOI was observed for significantly shorter time only with respect to the mouth AOI ($p = 0.022$). Finally, in the case of sadness facial expression, eye-right AOI was observed for significantly shorter time only with respect to the mouth and eye-left AOIs (all $p_s < 0.037$).

AOIs Fixation analyses of biased facial expression identification

Repeated-measures ANOVA performed on percentage of fixation revealed a significant main effect of AOIs ($F_{3,96}= 7.164$, $p = 0.000$; $\eta^2_p = 0.183$), as well as significant interaction Emotion by AOIs ($F_{3,96}= 4.554$, $p = 0.005$; $\eta^2_p = 0.125$) and Emotion by AOIs by Group ($F_{3,96}= 2.831$, $p = 0.042$; $\eta^2_p = 0.081$). Sidak post-hoc comparisons conducted on the main effect of AOIs showed that eye-right AOI received the lowest percentage of fixations, resulting significantly different from mouth and nose AOIs. (eye-right: 11.180 % SE=2.227; eye-left: 18.354%, SE=2.390; mouth: 29.330%, SE=3.008; nose: 20.825% SE=2.185; all $p_s < 0.038$). No significant difference was estimated between right and left eye AOIs.

Sidak post-hoc comparisons conducted on the interaction of Emotion by AOIs showed that mouth AOI received a significantly higher percentage of fixations during the observation of the facial expression of fear (33.585% SE 3.592) with respect to the facial expression of sadness (25.075% SE 3.229, $p = 0.013$). Differently, eye-left AOI received a significantly higher percentage of fixation during the observation of the facial expression of sadness

(20.981% SE=2.790) with respect to the observation of the facial expression of fear (15.727% SE=2.629, $p = 0.048$). Considering the facial expression of fear, the mouth AOI was the one receiving the highest percentage of fixations, resulting significantly different from all other AOIs (mouth AOI: 33.585 SE=3.592; all $p_s < 0.046$). Considering the facial expression of sadness, the eye-right AOI was the one receiving the lowest percentage of fixations, resulting significantly different from all other AOIs (eye-right AOI: 11.493 SE=2.181; all $p_s < 0.027$) with the exclusion of eye-left AOI ($p = 0.094$).

Sidak post-hoc comparisons performed on the interaction Emotion by AOIs by Group (see figure 8) revealed for Survivors a significantly higher percentage of fixations on eye-left AOI during the observation of the facial expression of sadness with respect to Controls (Survivor group: 28.151% SE=4.060; Control group: 13.810 SE=3.828; $p = 0.015$).

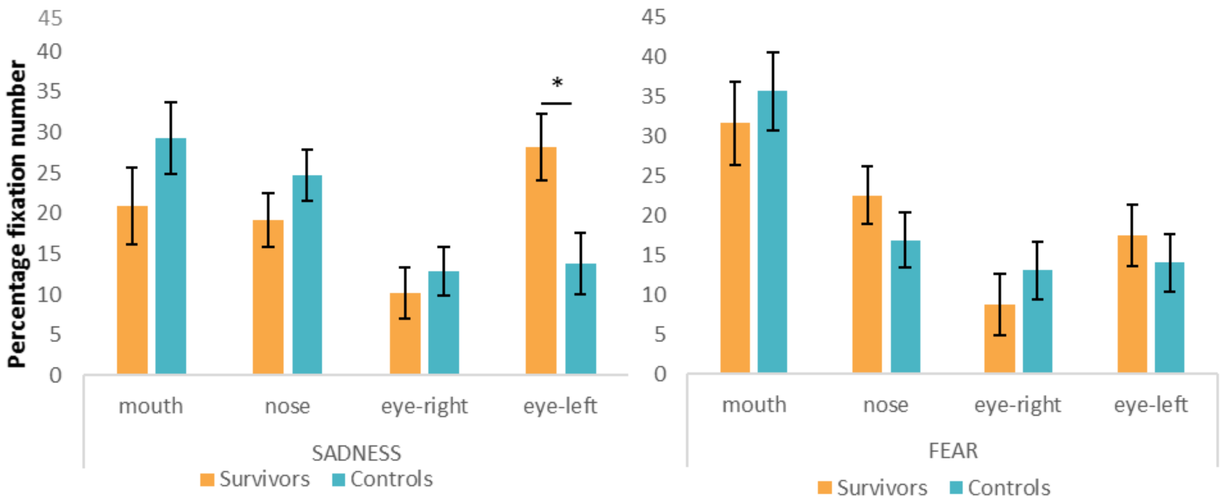

Figure 8. Percentage of fixation number during biased identification of sadness and fear.

Percentage of fixation number, between Survivor group and Control group, during biased sadness and fear expressions identification. * = p < 0.05; error bars depicted SE.

Mauchly's test conducted on participants' percentage of fixation duration showed a violation of sphericity assumption for AOIs factor ($\chi^2_{(5)}$ = 25.311, p = 0.000). Hence, degrees of freedom were adjusted using Greenhouse-Geisser correction (AOIs Ɛ = 0.685). Repeated-measures ANOVA performed on percentage of fixation duration revealed a significant main effect of AOIs ($F_{2.056,65.806}$= 4.496, p = 0.014; η^2_p = 0.123).

Sidak post-hoc comparisons performed on the significant main effect of AOIs factor revealed that eye-right AOI was the one significantly less observed with respect to all other AOIs with the exclusion of eye-left AOIs (eye-right: 12.347% SE=1.579; eye-left: 19.765%, SE=2.077; mouth: 21.425%, SE=1.715; nose: 20.187% SE=1.531; all p_s < 0.016).

AOIs fixation analyses comparing accurate and biased identification

Repeated-measures ANOVA comparing accurate and biased percentage fixation number during the identification of the facial expression of fear revealed a significant main effect of AOIs ($F_{3,99}$= 12.148, p = 0.000; η^2_p = 0.269) and a significant interaction Accuracy by AOIs by Group ($F_{3,99}$= 3.015, p = 0.034; η^2_p = 0.0854). Sidak post-hoc comparisons conducted on the main effect of AOIs showed that mouth AOI received the highest percentage of fixations, resulting significantly different from all other AOIs (eye-right: 10.145 % SE=1.986; eye-left: 16.451%, SE=2.301; mouth: 32.305%, SE=2.881; nose: 20.637%, SE=2.181; all p_s < 0.036). Furthermore, a significant difference was also found between the eye-right and the nose to the favor of the last one (p = 0.012). Sidak post-hoc comparisons conducted on the interaction Accuracy by AOIs by Group (see figure 9) showed a tendency among Survivor participants to display higher percentage of fixations on the eye-left when they correctly identified facial expressions of fear with respect to when they made a biased fear recognition performance (Accuracy: 22.517% SE=3.550, Bias:17.447% SE=3.775, p = 0.077). On the contrary, control participants displayed a higher percentage of fixations on the nose when they correctly identified facial expressions of fear with respect to when they made a biased fear recognition (Accuracy: 23.090% SE=3.053, Bias: 17.276% SE=3.303, p = 0.020).

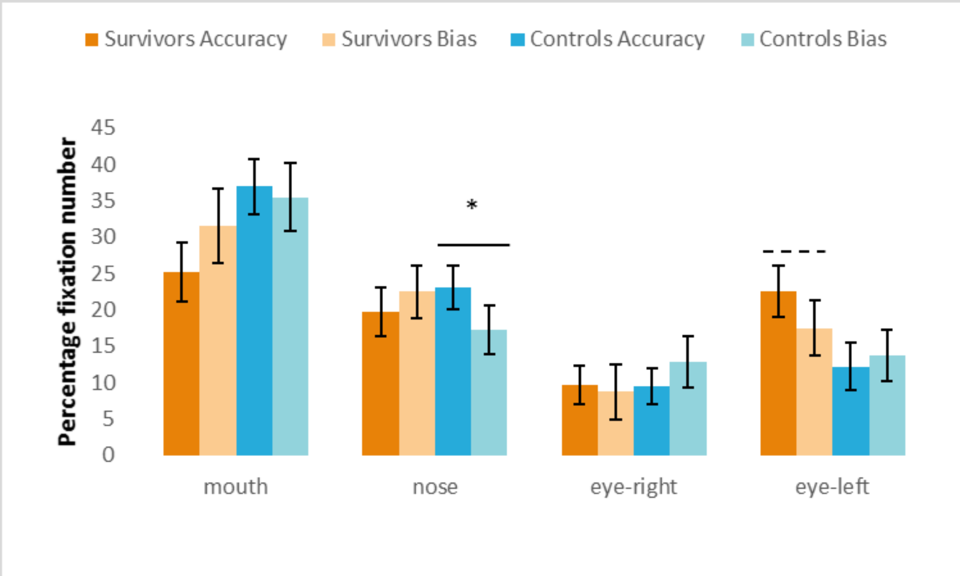

Figure 9. Percentage of fixation number comparing accurate and biased identification of fear. Percentage of fixation number comparing accurate and biased groups' identification of fear displayed for each AOI. * = p < 0.05; --- = p > 0.05; error bars depicted SE.

Mauchly's test conducted on participants' percentage of fixation duration showed a violation of sphericity assumption for AOIs factor ($\chi^2_{(5)}$ = 15.972, p = 0.007). Hence, degrees of freedom were adjusted using Greenhouse-Geisser correction (AOIs Ɛ = 0.764). Repeated-measures ANOVA comparing accurate and biased percentage of fixation duration during the identification of the facial expression of fear revealed a significant main effect of AOIs ($F_{2.293,75.683}$= 3.901, p = 0.011; η^2_p = 0.106). Sidak post-hoc comparisons performed on the significant main effect of AOIs revealed that mouth AOI was observed for longer time than eye-right AOI (mouth AOI: 21.764% SE=1.630; eye-right AOI: 13.679% SE=1.520, p = 0.009).

Mauchly's test conducted on participants' percentage of fixation number showed a violation of sphericity assumption for AOIs factor ($\chi^2_{(2)}$ = 18.819, p = 0.002). Hence, degrees of freedom were adjusted using Greenhouse-Geisser correction (AOIs ε = 0.801). Repeated-measures ANOVA comparing accurate and biased percentage of fixation number during the identification of the facial expression of sadness revealed a significant main effect of AOIs ($F_{2.404,134.634}$= 7.122, p = 0.001; η^2_p = 0.113) as well as significant interaction of AOIs by Group ($F_{2.404,134.634}$= 3.411, p = 0.028; η^2_p = 0.057). Sidak post-hoc comparisons performed on the significant main effect of AOIs demonstrated that eye-right AOI was the less observed one, with a significant difference with mouth and nose AOIs but with no significant differences with eye-left AOI (eye-right: 14.097% SE=1.751; eye-left: 17.585%, SE=1.797; mouth: 26.973%, SE=2.271; nose: 22.051%, SE=1.457; all $p_s < 0.020$).

Sidak post-hoc comparisons performed on the significant interaction AOIs by Group confirmed previous results, demonstrating that Survivor participants showed higher number of fixation percentage on eye-left AOI with respect to Control participants (Survivor group: 22.467% SE=2.542, Control group: 12.703% SE=2.542; p = 0.009).

An interesting near to significant interaction Accuracy by AOIs was found ($F_{2.293,63.500}$= 2.496, p = 0.062; η^2_p = 0.043) (see Figure 10). Sidak post-hoc comparison performed, in an explorative way, on this near to significant interaction revealed that both groups of participants produced a higher number of fixations on mouth AOI when they correctly recognized sadness facial expression with respect to when they committed a bias (Accuracy: 28.812%, SE=2.369; Bias: 25.626%, SE=1.504; p=0.004).

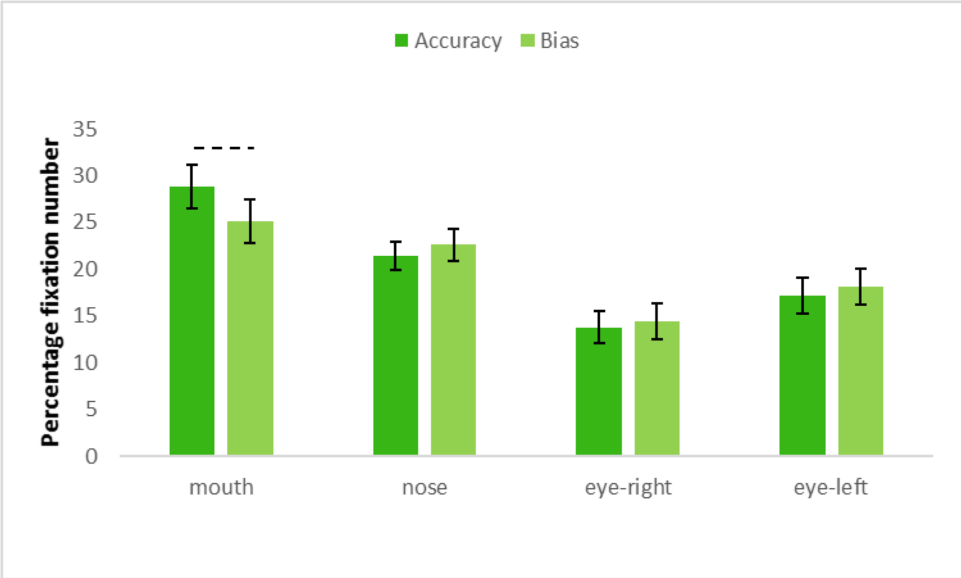

Figure 10. Percentage of fixation number comparing accurate and biased identification of sadness. Percentage of fixation number comparing accurate and biased participants' identification of sadness displayed for each AOI. --- = p > 0.005 (0.043); error bars depicted SE.

Mauchly's test conducted on participants' percentage of fixation duration showed a violation of sphericity assumption for AOIs factor ($\chi^2_{(5)} = 26.487$, $p = 0.000$). Hence, degrees of freedom were adjusted using Greenhouse-Geisser correction (AOIs $\varepsilon = 0.758$). Repeated-measures ANOVA comparing accurate and biased percentage of fixation duration during the identification of the facial expression of sadness revealed the significant mains effect of the factors Accuracy ($F_{1,56}= 36.903$, $p = 0.000$; $\eta^2_p = 0.397$) and AOIs ($F_{2.275,127.387}= 6.979$, $p = 0.001$; $\eta^2_p = 0.111$), as well as a significant interaction Accuracy by AOIs ($F_{2.754,154,198}= 8.367$, $p = 0.000$; $\eta^2_p = 0.130$).

Sidak post-hoc comparisons conducted on the main effect of Accuracy revealed significantly longer fixations when participants correctly recognized the facial expression of sadness than when they mistakenly identified them as the facial expression of anger (Accuracy: 20.289% SE=0.293, Bias: 18.342% SE=0.353).

Sidak post-hoc comparisons conducted on the main effect of AOIs revealed that regardless of participants' identification performance, eye-right AOI received significantly lower percentage of fixation duration respect to mouth and nose AOI, without significant difference with the eye-left AOI (eye-right: 13.753% SE=1.312; eye-left: 18.691%, SE=1.564; mouth: 23.676%, SE=1587; nose: 21.142% SE =1.152; all $p_s < 0.002$)

Lastly, Sidak post-hoc comparisons performed on the significant interaction Accuracy by AOIs (see figure 11) showed that when participants correctly recognized the facial expression of sadness they observed for longer time mouth AOI than when they committed a biased recognition (Accuracy: 28.812% SE=2.369, Bias: 18.541% SE=1.284, p = 0.000). On the contrary, when participants exhibited the recognition bias, they tended to observe for longer time eye-left AOI than when they correctly recognized the facial expression of sadness (Accuracy: 17.098% SE=1.923, Bias: 20.284% SE=1.661, p = 0.077).

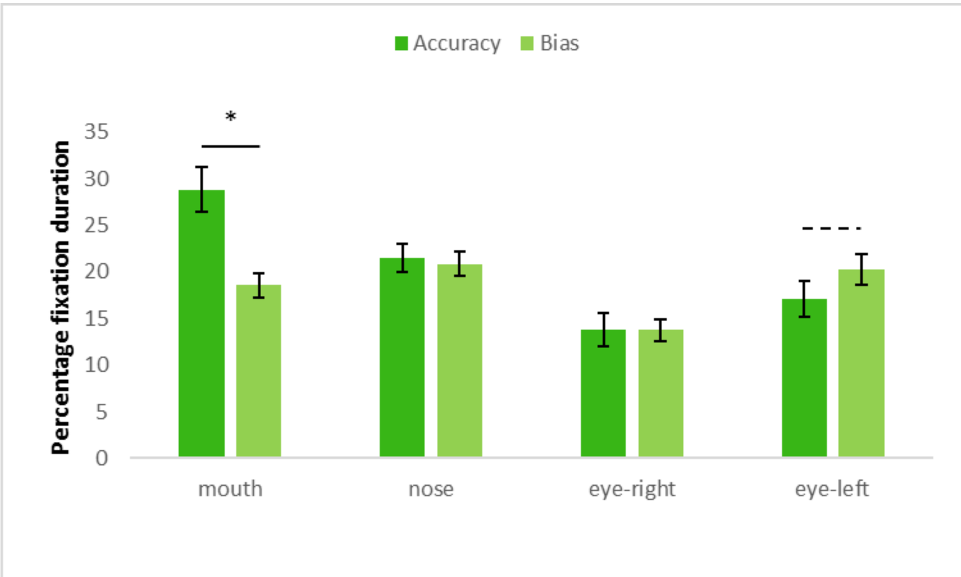

Figure 11. Percentage of fixation duration comparing accurate and biased identification of sadness. Percentage of fixation duration comparing accurate and biased participants' identification of sadness displayed for each AOI. * = p < 0.005; --- = p > 0.05; error bars depicted SE

4. DISCUSSION AND CONCLUSIONS

The aim of the present study was to investigate the visual scanning patterns underpinning higher perceptive and attentive functions involved in the recognition of others' facial expressions of emotions. In particular, the present subject of interest concerned the abovementioned low-level mechanisms that appeared altered in individuals exposed to traumatic experiences during childhood. The specific impairment in the recognition of the facial expression of emotions following trauma exposure consists in a bias in the recognition of the facial expression of anger. Specifically, victims of trauma tend to over-attribute anger when asked to identify other negative emotional expressions in a forced choice task. The presence of the bias in the recognition of anger has been confirmed in several studies involving underage participants with prolonged experiences of maltreatment, neglect and abuse (Pollak et al., 2000; Pollak & Sinha, 2002; Pollak & Kistler, 2002; Pollak et al., 2009; Ardizzi et al., 2013;2015). The bias in the recognition of anger was also found among children with a single intense trauma exposure (Scrimin et al., 2009). In addition, further results evidenced that also young adults with a childhood history of maltreatment, neglect and high violence exposure exhibit the same bias in the recognition of anger (Umiltà et al., 2013; Ardizzi et al., 2015). Bias persistence over time suggests that its underpinning mechanisms have been deeply altered in quite stable manner. The assumption was that early traumatic experiences can deeply modify the perceptual mechanisms, and their sensory thresholds, biasing the processing of the features of external stimuli that are more relevant in threatening environments. Despite the possible original adaptive value of these changes, in the long run they can cause defective regulation, processing and recognition of emotions (Pollak, 2008). However, it is still not clear if these alterations result from the establishment of a general response tendency among victims of trauma, or rather depend upon the increased perceptual saliency of specific anger expressive cues during the monitoring of the environment. Therefore, the present study was partly inspired by suggestions made by the literature about this issue (see for example Da Silva Ferreira et al., 2014) to further explore the low-level mechanisms involved in the bias in the recognition of angry facial expressions.

To accomplish this aim, a sample of underage Ebola virus disease survivors and a sample of peer controls, both coming from Sierra Leone, were recruited for the study. Previously, the PTSD Checklist for DSM-5 (PCL-5), the Impact of Event Scale-revised (IES-R) and the Cognitive Emotion Regulation Questionnaire short version (CERQ-short) were translated and validated following the cross-cultural adaptation process (Beaton et al., 2000). After that, these scales were administered to both groups in order to assess the presence of PTSD symptoms and psychopathologic signs caused by Ebola outbreak exposure. Furthermore, participants took part to a forced-choice facial expressions recognition task. During the task, participants' visual exploration patterns were recorded by means of an eye tracker. Given the relevance of the bias in the recognition of anger, the intent of the present study was to investigate the differences in the visual scanning patterns used by the two groups during both the correct and the biased recognition of facial expressions of emotions.

Questionnaire scores demonstrated that Ebola survivors showed higher presence of PTSD-related symptoms - as evaluated by the IES-R and PCL-5 questionnaires – with respect to controls. Emotion regulation while adapting to stressful life events, assessed by the CERQ-short questionnaire, demonstrated that Ebola survivors showed higher incidence of rumination and catastrophizing tendencies but also greater refocus on planning and positive reappraisal coping strategies with respect to controls. These results confirmed the traumatic nature of Ebola infection and related adversities (e.g., family members' death, hospitalization, stigmatization) able to induce PTSD-related sequelae and specific coping strategies among Ebola survivors.

Considering participants' performance with the forced-choice facial expression recognition task, in agreement with the literature and with no difference between the two groups, the facial expression of joy was the best recognized one, whereas the facial expression of sadness was the worst recognized one (Pollack et al., 2000; Pollack & Sinha, 2002; Umiltà et al., 2013; Ardizzi et al., 2013). A first unexpected result concerns the overall accuracy displayed by the two groups. The Survivor group was more accurate than Control group in the recognition of facial expressions of emotions. This result is at odds with previous studies where traumatized participants displayed significantly lower accuracy rates than controls (Ardizzi et al., 2013; 2015). Moreover, Survivors showed greater accuracy in the recognition of the facial expression of anger than Controls. This result is coherent with previous data (Gibb, 2009; Pollak et al., 2009; Ardizzi et al., 2013; 2015; Umiltà et al., 2013). The higher accuracy rate found for expressions of anger is in line with the tendency shown by individuals exposed to threatening environments to over-attribute anger when other negative emotions are observed. Despite previous studies showed lower accuracy rates in response to fear expressions among victims of trauma, in the present study Survivors showed a greater accuracy rate in the recognition of facial expressions of fear than Controls. This quite unexpected and never estimated before greater recognition ability displayed by Survivors with respect to controls, may depend on the different nature of trauma to which experimental populations were exposed. Previous studies involved victims of long-lasting and ongoing adverse experiences, like maltreatment and neglect. Differently, in the present study Ebola survivors were exposed to a well-defined, acute and, at the moment of the experiment, terminated traumatic experience (i.e., Ebola outbreak). This aspect may lead to different behavioral responses compared to chronic traumatic experiences. Thus, the higher accuracy rate displayed by Survivors in the recognition of all facial expressions of emotions and, in particular, of negative emotions (i.e., anger and fear) may conceal different implications arising from acuity instead of chronicity and, maybe, from different natures of trauma.

Nevertheless, both groups tended to erroneously over-attribute the anger label to the other negative emotions and especially to sadness rather than to fear. However, Survivors showed a significant higher over-attribution of anger than Controls, confirming that the bias in the recognition of anger arises not only from prolonged traumatic experiences but also from acute trauma, as an empirical study suggested before (Scrimin et al., 2009). The presence of a similar tendency among Controls may depend on the fact that, despite Controls had not been infected by Ebola virus and didn't loose any parent or relative, they were exposed to the outbreak and so they too experienced some distressful consequences of the outbreak. Similarity between experimental group's and control group's performance in the explicit recognition of facial expressions of emotions was also found in a previous study conducted with young participants (Ardizzi et al., 2015). The authors suggested that this general tendency may be related to the fact that skills involved in the recognition of emotions emerge in subsequent developmental stages, depending on the emotion. Recognition of joy facial expressions usually emerges earlier than that of other emotions (Sroufe, 1979). In particular, a first categorization distinguishes joy from non-joy (Herba & Phillips, 2004). This phenomenon could explain the high accuracy rate in the recognition of this emotion and the poorer performance with the recognition of negative emotions (Herba & Phillips, 2004). The effective distinction between negative emotions seems to appear at a later stage, starting from anger followed by sadness and fear (Herba & Phillips, 2004). From this point of view, the presence of the bias for anger, even if significantly lower among Controls, highlights the continuum between a normal mechanism and a so-called "abnormal" mechanism. This is an example of how, during specific periods of life, an abnormal mechanism might result from an abused use of a natural/normal predisposition belonging to a different stage of life.

An interesting and completely new result of the present study was the significant correlation between the bias rate in response to sadness and IES scoring. First, this result confirmed the reliability of the cross-cultural adaptation of the questionnaire. Second, for the first time the bias in the recognition of facial expressions of anger was associated with clinical evaluation of PTSD symptoms, demonstrating that these two phenomena are strongly related. The absence of a significant correlation between IES scoring and the bias rate in response to fear suggested that, at least among a population victim of an acute trauma, PTSD symptomatology was related especially with the manifestation of the bias during the visualization of sadness rather than fear. Considering also the higher incidence of the bias for the facial expression of sadness than of fear, it seems that the recognition of fear is more resistant than that of sadness. Interestingly, the presence of bias correlates with IES score and not with PCL-5 score. This result may be explained by the fact that the IES scale was administered by asking participants to answer considering the Ebola outbreak as traumatic event. Differently, PCL-5 is a diagnostic scale able to detect PTSD symptoms without specific reference to a traumatic event. Due to the sampling procedure followed to compare Ebola survivors with people not directly affected but exposed to the disease, IES can be more sensitive than PCL-5 to capture Ebola outbreak psychiatric *sequelae*.

Concerning eye-tracking analyses conducted regardless of AOIs (i.e. localization of fixations), no relevant differences were found between groups regarding both mean fixation number and mean fixation duration, neither when participants correctly recognized emotions nor when they showed bias in the recognition of anger. The only issue to emerge was that to correctly recognize joy all participants needed less number of fixations than to correctly recognize fear and sadness. This is consistent with the idea that joy identification takes less time and cognitive resources (Kirita & Endo, 1995; Leppänen et al., 2003). This effect is known as 'happy-face advantage' (Feyereisen et al., 1986). No between groups difference was estimated considering duration of fixations. Nevertheless, some differences between groups surfaced when analyses focused on the localization of fixations.

Among all participants, the mouth region received the higher percentage of fixation number when facial expressions were correctly labeled. Nevertheless, Controls looked to the mouth region significantly more frequently than Survivors. Differently, Survivors looked to the eye-left region significantly more frequently than to eye-right and both more frequently and longer than Controls when accurate. These general findings suggest that all Sierra Leonean participants did not exhibit the typical western scan path. Indeed, previous studies found that, in healthy western participants, the eye region is fixated more often and for longer periods compared with the other facial regions, independently from the specific emotion displayed (Spezio et al., 2007; Eisenbarth & Alpers, 2011; Wagner et al., 2014). In addition, accordingly with other studies, the best emotions recognition performance correlated with the left-side bias, that is, a higher number of fixation directed to the left space/right actor's hemi-face (Hsiao & Cottrell, 2008; Hsiao & Liu, 2012). Therefore, at first sight we could not see the classical western predominance of the eye region and left-side bias. On the contrary, Survivors looked eye-left significantly more than to the eye-right whereas among Controls this imbalance was absent. Therefore, Controls didn't exhibit the left-side bias and, on the contrary, it seems that Survivors exhibited even an opposite side bias compared to the well-known (for westerners) one.

Previous studies suggested that eye fixation strategies, when processing faces, may vary according to cultures. For example, Caucasians show a scattered triangular eye fixation pattern (eyes and mouth) in face recognition, whereas Asians exhibit a central (nose) eye fixation pattern (Blais et al., 2008). These results may reflect different meanings of eye contact in social communication, within different cultures. In both Asian and African cultures, direct eye contact can be seen as a lack of respect (Shipley & McAfee, 2015). In particular, many West African cultures exhibit a 'reluctance' to look another person directly in the eye, especially when the other person has an authoritative role (Jakson, 2004). Avoiding eye contact is a non-verbal way to communicate a recognition of the authority-subordinate relationship of participants in a social context. Also children are taught not to look another person in the eye, in particular when the other person is elder (Jakson, 2004). Looking into the eye of an adult communicates disrespect and can be perceived as a challenge to authority (Jakson, 2004; Shipley & McAfee, 2015). However, some differences between groups in the accurate recognition of emotions, should be highlighted. Controls focused on the mouth more than Survivors, while Survivors focused on eye-left more than Controls. Thus, if socialization rules have a role, it seems that Controls actually followed them more than Survivors. From this perspective, this result places Survivors a bit “out of the box”.

In particular, Survivors displayed a tendency to look more upon eye-left when they correctly labeled fear than when they committed a biased recognition. On the other side, Controls fixed significantly more the nose during correct identification of fear compared to a biased recognition. Therefore, Controls were facilitated by a central eye fixation pattern in correct fear recognition. On the other side, it seemed that Survivors were facilitated by a higher number of fixations in eye-left region. These results show that Survivor group and Control group exhibit very different visual scan paths when correctly performing fear recognition.

Concerning sadness recognition, all participants showed a tendency to fixate more upon the mouth region when they correctly identified sadness than when they committed a biased recognition. This result was just near to significance. However, all participants looked significantly longer at the mouth region when they correctly identified sadness compared to when they committed a bias in the recognition of anger. Moreover, when they committed a biased recognition of sadness, all participants showed the tendency to fixate more the eye-left region compared to correct performances. In the presence of bias in response to sadness facial expressions, Survivors fixated the eye-left region significantly more than Controls. Thus, it seems that when controls committed a bias in response to sadness they adopted the Survivors' visual exploration pattern.

Moreover, all participants, in the presence of bias, displayed more fixations to the mouth in response to fear than to sadness, and more fixations to the eye-left in response to sadness than to fear. According to the typical western scan paths, more fixations upon mouth in fear recognition, and more fixation upon eye region in sadness recognition should have facilitated the correct identification of these emotional expression (Eisenbarth & Alpers, 2011; Wagner et al., 2014), but this was not the case. Nonetheless, these findings may be less surprising considering as typical a scan path different from the western one.

The scan paths exhibited in the correct recognition of fear and sadness, confirm their divergence from typical western scan paths in which the eye region is the most frequently fixated in sadness (and anger) recognition, whereas the mouth region is significantly more fixated in fear than in sadness and anger (Eisenbarth & Alpers, 2011; Wagner et al., 2014). Our results highlight the opposite, especially during sadness recognition and especially among Survivors.

Even if all participants clearly exhibited scan paths different from the western ones, Survivors, but not Controls, displayed a similar exploration pattern in both correct and biased recognition performances. Survivors looked to the eye-left significantly more often and for longer time than Controls. Furthermore, the same pattern could be observed during biased performances, especially in response to sadness, which confirmed itself as the most effective emotion in eliciting the bias for anger. Although this is a preliminary study, it seems that Survivors were more sensitive to anger-related cues that can be found especially in the eye region rather than in the mouth region. This finding is consistent with previous results showing that abused children have more difficulties in disengaging attention from anger cues (Pollak & Tolley-Schell, 2003).

Survivors' tendency to look on eye (left) region more often and longer than Controls guided them to two divergent performances, one correct and the other one biased. Probably, when the recognition was biased, fixations on the eye region led them to anchor to anger-related cues. Vice versa, when the emotion recognition was correct, fixations on the eye region evidently provided them more useful information in order to perform correctly. By the way, this gaze tendency may contribute to explain why Survivors were more generally accurate than Controls. In this perspective, the traumatic experience that sadly hit them, might have shifted their classical scan path further from social rules concerning eye contact, from mouth region towards eye region. On the basis of the present data we cannot definitively explain why eye-left region was predominant compared to eye-right. However, it seems that the predominant attention given to eye region works, intermittently, both in an adaptive and maladaptive way. It would be adaptive when it provides further information in order to correctly recognize emotions and it would be maladaptive when it raises anger-related cues salience in favor of an over-attribution of anger label when sadness and fear are actually observed. As mentioned above, we seem to be contemplating the continuum between normal and "abnormal" mechanisms among individuals. We can see the continuum between adaptive and maladaptive mechanisms at work within individuals. This might help to fade a little the intellectual category of what is considered "maladaptive" in order to recognize, also in a maladaptive behavior, an effort of resilience.

Finally, it should be highlighted that the imbalance between number of bias in response to sadness and anger might have altered analyses, even if it may be not casual. Indeed, participants performed a significantly higher number of bias during the explicit recognition of sadness. In future, it would be interesting to introduce further measures as pupillometry, first fixation latency or broader AOIs including the entire half face in order to further explore and, eventually, confirm the side-bias found in the present study. Moreover, it would be very interesting to thoroughly explore bias-related scan path in the light of more detailed information concerning the overall scan path observed among all participants that appears so different from the western one.

In conclusion, our results showed for the first time the strong correlation between the presence of the bias for anger and clinical evaluations of PTSD symptomatology. In particular, we can confirm that, an acute trauma occurred during development, can be enough to cause perceptive alterations evident in specific visual scan paths during the exploration and forced identification of facial expressions of negative emotions. Nevertheless, some peculiarities emerged from the behavioral responses analyses of the traumatized group, leading to hypothesize that different traumatic experiences, at least in acute/chronic terms, can differently affect the correct recognition of emotions. Further studies could confirm this difference and highlight if it is merely quantitative or qualitative too. If the ability to recognize the facial expression of emotions is crucial, together with other skills, for social competence (Mostow et al., 2002), an altered perceptual mechanism of the facial expression of emotions might, at least partially, explain the reason why an adaptive social functioning results altered in individuals exposed to early aversive experiences (Van der Kolk et al., 2001; Cook et al., 2005; Cloitre et., 2009; 2013; Sar, 2011).

Present and future results, within a virtuous circle including the contribution of psychodynamic and ethno-psychiatric approach, could guide clinical diagnosis to be less rigid and treatments to be more personalized according to the kind of victims' trauma, personal characteristics, and cultural belonging.

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