Neurocognitive reorganization of emotional processing following a socio-cognitive intervention in Colombian ex-combatants

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ABSTRACT

Ex-combatants often exhibit atypical Emotional Processing (EP) such as reduced emphatic levels and higher aggressive attitudes. Social Cognitive Training (SCT) addressing socio-emotional components powerfully improve social interaction among Colombian ex-combatants. However, with narrow neural evidence, this study offers a new testimony. A sample of 28 ex-combatants from Colombian illegal armed groups took part of this study, split into 15 for SCT and 13 for the conventional program offered by the Governmental Reintegration Route. All of them were assessed before and after the intervention with a protocol that included an EP task synchronized with electroencephalographic recordings. We drew behavioural scores and brain connectivity (Coherency) metrics from task performance. Behavioural scores yielded no significant effects. Increased post-intervention connectivity in the delta band was observed during negative emotional processing only SCT group. Positive emotions exposed distinctive gamma band connectivity that differentiate groups. These results suggest that SCT can trigger covert neurofunctional reorganization in ex-combatants embarked on the reintegration process even when overt behavioural improvements are not yet apparent. Such covert functional changes may be the neural signature of compensatory mechanisms necessary to reshape behaviours adaptively. This novel framework may inspire cutting-edge transational research at the crossing of neuroscience, sociology, and public policy-making.

KEYWORDS emotional processing, ex-combatants, socio-cognitive training, EEG, functional connectivity

INTRODUCTION

Just in the last decade, around 50,000 Colombian ex-combatants have returned to civil life and enrolled in governmental reintegration programs (Agencia para la reincorporación y normalización, 2018; Kaplan & Nussio, 2013). Thus, the country has become a key example on how to implement a person-centred reintegration route aimed at demobilized combatants (Trujillo, Trujillo, Lopez, et al., 2017). Combat experience is often associated to stress-induced cognitive atypical functioning and to an increase of mental health risks, such as lower quality of life perception and higher prevalence of mental disorders (Castro, Adler, McGurk, & Bliese, 2012; Godfrey et al., 2015; Weierstall, Castellanos, Neuner, & Elbert, 2013). Furthermore, diminished empathic disposition (Tobón et al., 2015; Trujillo, Trujillo, Ugarriza, et al., 2017), increase among aggressive attitude and violence (Gallaway, Fink, Millikan, & Bell, 2012; Godfrey et al., 2015; Tobón et al., 2016), and antisocial behaviour (Kaplan & Nussio, 2013) have also been informed. Particularly, atypical Emotional Processing (EP) has been consistently reported among ex-combatants (DiGangi et al., 2018; Khanna et al., 2017; van Rooij et al., 2015). DiGangi et al. (2017) showed an association between attenuated late positive potential (LPP) for angry faces with the severity of post-traumatic stress disorder (PTSD) symptoms in ex-combatants during an emotional face-matching task. Differences in functional brain connectivity associated to anger and aggression levels during emotional pictures presentation have also been informed in war veterans (Heesink et al., 2018).

Colombia has suffered an armed conflict of more than six decades. In a previous study with Colombian ex-combatants, we observed atypical behavioural and electrophysiological EP markers associated to imprecise valence attribution for faces, words, and ecological images (Quintero-Zea et al., 2017; Tobón et al., 2015; Trujillo, Valencia, et al., 2017). Additionally, we described a differential neural pattern represented by the modulation of the N170 component during EP; i.e., ex-combatants privilege face processing over verbal content as a potential neural strategy to improve the recognition of meaningful social information provided by their environment (Trujillo, Valencia, et al., 2017). Furthermore, larger amplitude in the LPP component related to the recognition of valence in contextual emotional images and its association to lower emphatic personal distress dimension have also been informed (Tobón et al., 2015). Compared to civilians, Colombian ex-combatants additionally show significant EEG functional connectivity network differences during EP. Specifically, they present increased leaf fraction in delta, theta, alpha and beta bands and a reduced diameter in delta, theta and alpha bands. Features such as the Leaf fraction–Diameter in delta band during face processing, and in alpha band during word processing, were identified as phenotypic features of ex-combatants. Such features indicate they may rely on different brain mechanisms to process emotional stimuli (Quintero-Zea et al., 2018). In addition, ex-combatants show lower functional connectivity for positive images in the beta band in centro-parietal and parieto-occipital regions (Rodríguez-Calvache, 2017) –a frequency range that is sensitive to emotional processing (Ray & Cole, 1985), and that discriminates between positive and negative stimuli (Bos, 2006).

In summary, evidence enables establishing an atypical neural activity associated to specific patterns of social behaviour (such as EP, social skills, and empathy) as a potential adaptive response towards war environments (Quintero-Zea et al., 2017; Tobón et al., 2015; Trujillo, Valencia, et al., 2017). Nevertheless, there is limited evidence about how these patterns (i.e. neural functional reorganization) can be modified in ex-combatants under a reintegration process by using cognitive interventions (Trujillo, Trujillo, Lopez, et al., 2017). This presents a unique context to improve the existing intervention routes thorough the implementation of neurophysiological evidence-based evaluation, and to characterize changes among such individuals towards improved target interventions.

Cognitive interventions based on training of socio-emotional components have shown effectiveness to improve social interaction among individuals with schizophrenia, dementia, traumatic brain injury, and Colombian ex-combatants (Hooker et al., 2012; Roelofs, Wingbermühle, Egger, & Kessels, 2017; Tan, Lee, & Lee, 2018; Trujillo, Trujillo, Lopez, et al., 2017). Furthermore, previous studies reported changes in functional brain connectivity in frontal and parietal areas associated to cognitive interventions in healthy and pathological ageing individuals (Cespón, Miniussi, & Pellicciari, 2018). In patients with schizophrenia, Campos et al. (2016) showed improvements in social outcomes and changes in brain activity by increasing activation in frontal and parietal areas associated to a SCT. In a recent study with Colombian ex-combatants, we identified accuracy improvements recognizing neutral faces in former combatants who received a SCT (Trujillo, Trujillo, Lopez, et al., 2017). However, to our knowledge, the underlying neural mechanisms of the SCT that might drive pattern changes in social cognitive behaviours of ex-combatants remain unknown.

Against this background, the present study aims to investigate whether a brief SCT delivered to Colombian ex-combatants which has proved useful to enhance social cognition and improve emotional regulation (Trujillo, Trujillo, Lopez, et al., 2017) can induce reorganization of the physiological activity linked to such cognitive functions. Our main hypothesis was that relative to the standard program delivered by the Agency for Reincorporation and Normalization (ARN, http://www.reintegracion.gov.co/es/agencia), which does not train EP, the SCT would promote reorganization of neurophysiological associated to EP. The present study will further contribute to such a research area by providing novel evidence drawn from brain network connectivity.

MATERIALS AND METHODS

Participants

The sample consisted of 28 participants (26 men, 2 women) from the ARN, a governmental agency that coordinates and implements the reintegration route for demobilized individuals from illegally armed groups, to facilitate their return to civilian life. The sample had a mean age of 37.32 (*SD* 7.94) years old and an average of 10.36 (*SD* 3.02) years of education. The group was divided in two groups: the first one received an adapted Social Cognitive Training Group (SCTG), which involved 15 subjects (13 men, 2 women). We agreed with the ARN that participants from SCT group would only participate on this intervention during its whole duration. The second group continued with the Conventional Reintegration Group (CRG) and involved 13 subjects (all men). The two groups completed a pre-intervention protocol (time 1 – T1) and a post-intervention protocol (time 2 – T2). The assessment was performed by two blind-trained psychologists. Figure 1 describes the stages of the study and the selection of the sample. All participants reported no mental health illness history. They read and signed the informed consent document before beginning the study. This consent contained information about the aim of the study, procedures, intervention protocol (12 sessions), confidentiality management, and voluntary participation. The research protocol was approved by the Bioethical Committee of the Faculty of Medicine at University of Antioquia, Medellin, Colombia. The SCT invitation process is detailed in Trujillo, Trujillo, Lopez, et al. (2017) and summarized below.

[INSERT FIGURE 1]

Intervention program

The SCT is a twelve sessions intervention program developed for Colombian ex-combatants (Trujillo, Trujillo, Lopez, et al., 2017). The aim of this training is to improve emotional recognition skills towards basic emotions (sessions 1 to 3); social skills and assertive expression of emotions (sessions 4 to 8); and theory of mind and social cues reading (sessions 9 to 12). Each session integrated: i) discussions about hypothetical social situations; ii) role-playing of social scene; iii) analysis of daily social interactions; and iv) homework using the knowledge reached on each session. The SCT was applied by a trained psychotherapist, where each participant assisted to a 45 minutes session per week for 12 weeks. The CRG continued with the conventional reintegration program, which consisted of 45-60 minutes weekly sessions based on individual plan agreement adapted for each participant by reintegration agency. The sessions include different lectures and discussion about family life, education, productivity, safeness, community challenges and improvements in daily life performance.

Experimental task

Contextual valence recognition task (CVT)

A task for identifying contextual valence images was implemented in E-prime (Psychology Software Tools, Pittsburgh, PA, United States). The task was based on the International Affective Picture System (IAPS) (Lang & Bradley, 2007). The CVT used 60 pictures from IAPS selected according to their valence as informed in the Colombian validation by Gantiva Díaz, Guerra

Muñoz, & Vila Castellas (2011). Images were categorized, according to their valence in three conditions: 20 positive, 20 neutral, and 20 negative ones. The task was divided in four blocks of 60 trials each (for a total of 240 trials). Each stimulus was presented four times in a random order. The CVT task was presented in a 17-inch PC screen at 60 cm from the participants. The task sequence (shown in Figure 2) consisted of a fixation cross presented for 1000 ms, an inter-stimulus interval ranging from 700 to 1000 ms. followed by the stimuli (IAPS image) presented for 500 ms, and finished with a black screen with a fixation cross in the center awaiting for the participant to response for a maximum time of 10 s. Participants were asked to decide the valence of the stimuli pressing one of three keys of a PC keyboard.

[INSERT FIGURE 2]

EEG recordings

Tasks were synchronized with EEG recordings. EEG registers were acquired with a 64 electrodes EEG NeuroScan SynAmps2 amplifier at a sample rate of 1000 Hz. The electrodes were placed according to the international 10-20 system with EEG-caps. Impedances were kept below 10 kΩ. The recordings were performed in a Faraday cage with controlled illumination.

Signal processing

All EEG recordings were pre-processed in EEGLab toolbox for MATLAB. The signals were downsampled from 1000 Hz to 500 Hz and offline re-referenced to mastoids. Signals were band-passed using an IIR filter with cut frequencies of 0.1 to 59.9 Hz. Independent Component Analysis (ICA) for EEGLab was performed and used to remove oculomotor artefacts. Task-related EEG was epoched (i.e., Conditions: positive, neutral, and negative valence) with 1 s windows (-200 to

800 ms locked to stimulus onset). The epochs were baseline corrected using the time window -200 to 0 ms. Finally, signals corresponding to each epoch were visually inspected and any remaining artefacts were manually removed.

Functional connectivity analysis

We used a phase synchronization metric called Imaginary Part of Coherency (iCOH) to reduce volume conduction artefacts (Nolte et al., 2004). This approach has been previously used to evaluate clinical population (e.g. autism spectrum disorder (García Domínguez, Stieben, Pérez Velázquez, & Shanker, 2013) and ex-combatants (Rodríguez-Calvache, Quintero-Zea, Trujillo, Trujillo, & López, 2017). We extracted specific frequency bands associated to cognitive processes: delta (0.1 to 4 Hz), theta (4 to 8 Hz), alpha (8 to 14 Hz), beta (14 to 30 Hz) and gamma (30 to 60 Hz) using HERMES toolbox for MATLAB (Niso et al., 2013). We defined four regions of interest (RoI) based on previous work reported by Rodríguez-Calvache (2017): RoI1: F1, F3, Fc1 and Fc3; RoI2: F2, F4, Fc2 and Fc4; RoI3: P1, P3 PO3 and Po5; RoI4: P2, P4, Po4 and Po6. Relying on such regions, we calculated the iCOH across six pairs. Pair 1: RoI1-RoI2; Pair 2: RoI1-RoI3; Pair 3: RoI1-RoI4; Pair 4: RoI2-RoI3; Pair 5: RoI2-RoI4; and Pair 6: RoI3-RoI4.

Statistical analysis

This study followed a pre-post mixed design model. Demographic variables were analysed using independent-samples t-test and Chi2 (for gender) to establish baseline differences in demographic variables across groups.

To analyse the behavioural data of CVT, we calculated the mean accuracy (percentage of correct responses), reaction time for correct answers, and error type (percentage of incorrect responses within each alternative valence, e.g., positive stimuli with an assigned neutral or negative answer) for subject and condition. A mixed ANOVA model was used to analyse accuracy and reaction time. Within-subject factors were Time (T1 vs. T2, i.e. before and after the SCT) and Condition (Positive vs. Neutral vs. Negative), and the between-subjects factor was Group (SCTG vs. CRG). The same model was used to analyse error type. For significant interactions, we calculated the Index of Change as the T2-T1 discrepancy for each relevant variable and we entered these values to FDR corrected *post hoc* tests.

For the EEG functional connectivity analysis, we implemented a mixed ANOVA for each band (delta, theta, alpha, beta, and gamma) independently. Within subject factors were Time (T1 vs. T2), Condition (Positive vs. Neutral vs. Negative) and Pairs [Pair 1 (ROI1-ROI2) vs. Pair 2 (ROI1-ROI3) vs. Pair 3 (ROI1-ROI4) vs. Pair 4 (ROI2-ROI3) vs. Pair 5 (ROI2-ROI4) vs. Pair 6 (ROI3-ROI4)]. The between-subjects factor was Group (SCTG vs. CRG). To explore the effects of the SCT, we focused on significant interactions involving Time and Group factors. Follow up *post hoc* tests for significant interactions included the Index of Change which entered independent-sample or paired-samples t-tests whose outcomes were FDR corrected. We report the adjusted p-values (i.e., q-values). For interactions we report the effect size returned by the models (η^2: small = 0.01, medium = 0.06 and large = 0.14) and power (β), whereas for *post hoc* analyses the effect size was calculated using Cohen's *d* (small = 0.2, medium = 0.5 and large = 0.8) (Fritz, Morris, & Richler, 2012).

RESULTS

Demographic and Behavioural Analysis

Analysis of Demographic data showed no significant differences between Groups regarding age (t=1.01; p=0.3), years of education (t=-0.044; p=0.96), or gender (χ^2 = 1.867 p:0.48). ANOVA models including Time by Group comparisons of variables that form the experimental task revealed no significant effects (see Supplementary Material supplementary table 1 for further details).

[INSERT TABLE 1]

Brain Connectivity Analysis

Functional connectivity analyses revealed significant effects involving Time by Group comparisons only in the delta and gamma bands. We therefore focused on these bands (see Supplementary Material table 2 for descriptive statics). Table 2 shows mixed ANOVA results and post hoc analysis for Delta and Gamma band. For delta we found a significant Time by Condition by Group interaction. *Post hoc* analyses were carried out across Conditions for Groups separately entering the Index of Change. Significant effects were found for contrasts between positive vs. neutral for the SCTG and CRG as well as neutral vs. negative conditions. The SCTG showed significant differences between positive vs. negative conditions, an effect not found in the CRG (see Supplementary Material table 3.1 for full comparisons). Additional *post hoc* analyses carried out across Groups for Conditions separately showed significant Group effects (SCTG > CRG) for negative stimuli (see Supplementary Material table 3.2 for full comparisons).

[INSERT TABLE 2]

The three way interaction Time by Pair by Group was also significant (see table 2). *Post hoc* analyses carried out across Pairs for Groups separately showed no significant effects in the SCTG. The CRG showed significant differences between Pair 2 vs. 3 and 3 vs. 4 (see Supplementary Material table 3.3 for full comparisons). Additional *post hoc* analyses carried out across Groups showed significant differences between Groups (SCTG > CRG) for Pair 2. No other contrasts reached significance.

Crucially, Time by Condition by Pair by Group interaction was significant (see table 2). *Post hoc* analyses were carried out across Pairs by Conditions by Groups separately entering the Index of Change. SCTG showed significant differences between Pair 2 vs. 4. CRG showed significant differences between Pairs 2 vs. 3, 3 vs. 4 and 4 vs. 5 (see Supplementary Material tables 3.5, 3.6 and 3.7 for full comparisons). All these significant effects were observed for negative stimuli only. Additional *post hoc* analyses carried out across Groups showed significant differences (SCTG > CRG) for Pair 2 and Pair 4 for negative stimuli too. No other contrasts reached significance (see Supplementary Material table 3.8 for full comparisons).

Finally, to ensure baseline discrepancies could not account for above presented effects we carried out comparisons using data from T1 and T2 across Groups for negative stimuli (the one yielding significant effect above) collapsing across Pairs. Contrasts revealed that SCTG and CRG did not significantly differ in brain connectivity metric in delta band at T1 [$t(26)= -0.227$; $p=0.822$] but they did at T2 [$t(26)= 2.83$; $p=0.009$]. The SCTG showed a significant T1-T2 discrepancy [$t(1)= -3.84$; $p=0.002$] not observed in the CRG [$t(12)= 0.63$; $p=0.538$]. Supplementary table 8 summarized in a graphical format the key outcomes from brain connectivity analysis.

The analysis within gamma band showed a significant Time by Condition by Group interaction (see table 2). *Post hoc* analyses carried out across Groups for each Condition showed significant differences for positive stimulus (SCTG > CRG). Additional *post hoc* analyses carried out across Conditions for each Group separately entering the Index of Change did not reach significance after multiple comparisons correction (see Supplementary Material supplementary table 7.1 and 7.2).

In summary (see Table 2), functional connectivity analyses revealed a post-intervention enhancement which was more robust in SCTG and was characterized by a seemingly functional reorganization of a brain network with a hub located on the left fronto-central regions. Ipsi and contralateral connections of such a hub displayed the most significant changes in the SCTG group when the here calculated Index of Change was considered. This reorganization was (i) evident during the processing of Negative Stimuli, (ii) focal in the SCTG while widespread in the CRG, and (iii) larger in SCTG than in CRG. Regarding positive stimuli, changes from T1 to T2 were characterized by an increase in brain connectivity which was more pronounced in SCTG. We now proceed to discuss such findings.

DISCUSSION

The present study was set out to investigate whether a brief SCT program delivered to Colombian ex-combatants would induce reorganization of physiological activity from brain networks supporting EP. We hypothesised that those who receive such a programme would more likely show such a reorganization. We envisaged that such networks changes could be potential drivers of results previously reported by our group (Trujillo, Trujillo, Lopez, et al., 2017). We also hypothesised that such a reorganization would not be observed in ex-combatants enrolled in the conventional program offered by the Reintegration Agency because that program does not seek to enhance social cognition and EP. These hypotheses proved to be true. We discuss the significance of these findings in turn.

Using an EP task synchronized with EEG, we observed a neural reorganization associated to SCT program, mainly in delta and gamma bands. To our knowledge, this is the first study that reports about the association between a social cognitive training and functional network modulations in non-clinical ex-combatants. Previous studies in schizophrenia and autism (Hajós, 2006; Sun et al., 2012) found that delta and gamma bands might serve as a biomarker to monitor the function of cognitive and emotional processed in social contexts, and that this could outperform the analysis of behavioural responses for such a purpose. The delta band has been implicated in different cognitive processes such as motivation, behavioural inhibition, and attention (Harmony, 2013). Specifically, increased delta band activity has been associated to concentration and related to a specific inhibition process that selectively suppresses neural activity not relevant for a particular cognitive process (Harmony, 2013). According to the literature, there is a variation in delta band activity for facial emotional stimuli when compared to neutral stimuli (Knyazev, Slobodskoj-Plusnin, & Bocharov, 2009). In our study, both the SCTG and CRG showed differences for emotional (positive or negative) and neutral stimuli; however, differences linked to processing of negative stimuli were significantly larger in SCTG than in CRG.

These findings suggest that the SCT intervention delivered to SCTG led to a consistent increase of network activity in delta band associated to negative stimuli. This could reflect specific adaptive neuromodulation to stimuli of negative valence and/or attenuation of interference from other valances which might not be that relevant to war contexts wherein ex-combatants have spent years

(Harmony, 2013). It has been previously suggested that chronic exposure to war conflicts may lead to an emotional dedifferentiation (Trujillo, Trujillo, Lopez, et al., 2017; Trujillo, Valencia, et al., 2017) whereby processing negative emotions become habituated and thus valences across the spectrum of emotions become undifferentiated. To be able to successfully read social cues and enhance social cognition functions the ability to identify individual emotions out of this continuum needs to be restored. More efficient neural mechanisms responsible for processing negative stimuli would lead to reduced aggressive attitudes (see Trujillo, Trujillo, Lopez, et al., 2017) and improved cognitive and inhibitory mechanisms necessary to adapt to everyday situations (Ochsner et al., 2004; Tipper, 2001). Our findings suggest that increased activity in delta band for SCTG can be signalling enhanced attention and inhibition mechanisms evidenced by CVT. Such mechanisms would strengthen endogenous attention functions which would in turn grant access to specific domains along the emotional spectrum where negative valences play a key adaptive role (Pan, Wu, Zhang, & Ou, 2017; Vuilleumier, 2005). These findings are relevant inasmuch as they highlight potential patterns associated to aggressive behaviours, areas where such patterns can be modified, and strategies (e.g., SCT) through which such modifications can be achieved (Chapin & Russell-Chapin, 2013).

Regarding network activity in gamma band, we observed that significant findings emerged from analysis including Positive emotions. Whereas SCTG describe an increase in brain connectivity, CRG showed reduced connectivity from T1 to T2 across all explored regions. These results and potential accounts could be i) faster habituation to (i.e., learning) positive emotions particularly if one is not enrolled in an emotion recognition training program (GRG), ii) relevance of positive emotions to restore the differentiation of emotions along the spectrum (SCTG showed larger variation from T1 to T2). Note that the significant Time by Group interaction observed during this analysis was uncounted for by baseline differences (ANCOVA controlling for T1 differences $F(1,25)=55.12$, $p<0.001$, $\eta 2=0.68$, $b=1.00$) (Favrod et al., 2015; Favrod et al., 2019; Nguyen et al., 2016).

Balconi & Lucchiari (2008); and Li, Cao, Wei, Tang, & Wang (2015) described differences in gamma band activity between patients with depression and controls, whereby controls exhibited increased gamma band activity during emotional face processing tasks. Consistent with the literature, increased gamma band activity is related to processing of positive emotional images compared to neutral images in healthy population (Aydin, Demirtaş, Ateş, & Tunga, 2016; Güntekin, Femir, Gölbaşı, Tülay, & Başar, 2017). In line with our suggestions above, our findings indicate that throughout the SCT, ex-combatants' reliance on functions linked to positive emotion processing were kept active (t-tests comparing pre-post connectivity showed an increase for SCTG $t=3.701$ whereas a pronounced decrease was observed in CRG $t=10.78$). It might be that positive emotions levered the processing of negative emotions thus enabling the reorganization of the network supporting the latter emotion. Future research will be necessary to investigate the interplay of emotions in the emotional dedifferentiation that occurs in individuals experiencing chronic EP disturbances.

A final finding worth discussing is the discrepancy between outcomes from the analyses of behavioural and brain connectivity variables. While the latter proved sensitivity enough to capture subtle changes induced by a SCT program aimed at restoring EP, the former did not. Accrued wisdom has confirmed that subtle electrophysiological changes can remain subthreshold for long periods before they express behaviourally/clinically (Chapin & Russell-Chapin, 2013). There is a plethora of studies confirming the presence of subclinical/subthreshold electrophysiological responses (Chapin & Russell-Chapin, 2013; Olbrich, van Dinteren, & Arns, 2015), which have provided the basis to suggest that electrophysiological tools can deliver biomarkers to detect the early and even preclinical stages of neuropsychiatric disorders. Our current findings allow us to join this view and suggest that adding the analysis of EEG-based connectivity to assessment protocols aimed at detecting the impact of SCT program in populations affected by longstanding conflicts would enhance the sensitivity of the assessment and the likelihood of measuring the efficacy of such programs.

LIMITATIONS AND FUTURE RESEARCH

There are some limitations of this study that must be considered. The main one is the sample size. Due to particular features of the studied population (e.g., chronic exposure to war, frequent change of residence and safety issues) access to large samples of subjects have proved challenging. In addition, it was not possible to guarantee randomization of the sample due to logistic difficulties (we did not have access to a large population of ex-combatants, and from the available sample many presented security, health or transportation issues). Future replication studies should consider alternatives to guarantee a randomized sample. Therefore this study should be consider as an open uncontrolled trial. Nevertheless, we concentrated our efforts on avoiding potential interpretation bias by (i) focusing on results from controlled statistical models, (ii) controlling for Type-I error (e.g., FDR), (iii) and choosing only results were interaction models involving key variables (i.e., Time) proved significant. Although this does not rule out the need of assessing larger samples of ex-combatants, it grants us confidence to suggest that the current study provides valuable cues to guide future research. Additionally, we did not obtain psychiatric profiles of our participants. These would allow investigating adaptive mechanisms and control for potential confounding factors such as mental health illnesses. Future studies should take care of this limitation.

CONCLUSION

We provide here preliminary evidence of functional reorganization of brain network involved in EP following a short SCT intervention administered to a small sample of Colombia ex-combatants. To our knowledge, this is the first study that evaluates the EP neural reorganization associated to a SCT intervention in ex-combatants. Our results suggest that some emotions play a key role in the restoration of emotional differentiation along the emotional spectrum in individuals in whom such a spectrum has collapsed due to a chronic exposure to negative experiences. Such differentiation seems to place different weights on specific emotions. Overt functional brain network reorganization in support to EP after SCT can be observed during still covert (subthreshold) behavioural responses. The actual role of the observed brain network changes in the restoration of behaviours linked to EP will need further research.

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DISCLOSURE OF INTEREST

The authors report no conflict of interest

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Table 1. Descriptive statistics for demographic variables and behavioural CVT data

	SCTG		CRG	
Demographic				
Gender M:F	13:02		13	
Age	38.73 (7.85)		35.69 (8.05)	
Years of education	10.33 (3.02)		10.38 (3.15)	
	Time 1	**Time 2**	**Time 1**	**Time 2**
	M (DS)	**M (DS)**	**M (DS)**	**M (DS)**
Accuracy				
Positive	67.59 (19.69)	66.58 (22.00)	56.80 (25.86)	56.80 (21.16)
Neutral	35.38 (19.91)	45.38 (17.71)	58.44 (16.27)	62.34 (20.50)
Negative	72.13 (28.30)	89.25 (10.76)	88.13 (12.23)	92.03 (4.28)
Reaction time				
Positive	680.67 (177.12)	871.61 (247.83)	570.04 (195.81)	582.63 (254.43)
Neutral	867.96 (292.26)	1085.24 (307.50)	623.34 (203.16)	667.54 (250.24)
Negative	594.03 (139.96)	738.23 (211.93)	487.01 (187.80)	502.39 (174.56)
Error type				
Positive error neutral	15.58 (14.21)	23.66 (17.98)	21.84 (17.13)	30.38 (19.71)
Positive error negative	13.15 (9.83)	10.42 (9.83)	16.56 (15.22)	10.78 (13.06)
Neutral error positive	53.65 (20.54)	39.62 (11.11)	36.67 (15.81)	35.94 (21.99)
Neutral error negative	16.35 (7.51)	15.10 (13.33)	17.81 (15.28)	12.81 (11.72)
Negative error positive	14.90 (13.20)	5.38 (7.42)	8.23 (10.12)	8.33 (13.52)
Negative error neutral	11.15 (14.98)	5.19 (3.78)	6.77 (7.88)	4.69 (3.70)

M: mean SD: standard deviation. SCTG: Social Cognitive Tainted Group. CRG: Conventional Reintegration Route Group.

Table 2. Summary of significant Mixed ANOVA effects and contrasts revealed by post-hoc tests carried our across Groups, Times, Conditions and ROI Pairs.

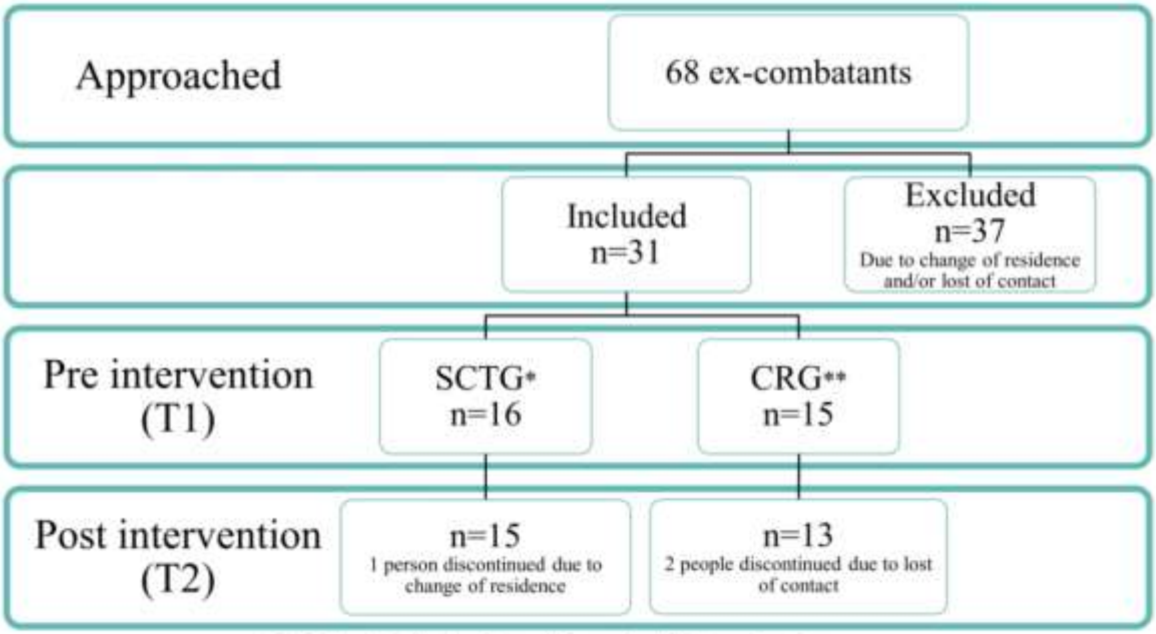
	Mixed ANOVA		***Post hoc* comparisons**		
			Within-Subjects [T, q, d]		**Between-Subjects [T, q, d]**
		[F(*df*), p, n^2, b]	**SCTG (*df=14*)**	**CRG (*df*=12)**	**(*df=26*)**
Delta band	Time by Group	NS	NA	NA	NA
	Time by Condition by Group	[4.18(2), 0.02, 0.14, 0.71]	P < N [-10.98, 0.00, -4.00] P < Ne [-3.70, 0.00, -1.05] N < Ne [10.94 0.00, 3.99]	P > N [-6.61, 0.00, -2.58] N > Ne [6.58, 0.00, 2.59]	Ne SCTG > CRG [3.18(26), 0.011, 1.24]
	Time by Pair by Group	[3.37(5), 0.01, 0.11, 0.89]	NS	Pair 2 < 3 [-3.64, 0.02, -0.60] Pair 3 > 4 [4.25, 0.02, 0.77]	Pair 2 SCTG > CRG [2.93(26), 0.04, 1.11]
	Time by Condition by Pair by Group	[1.97(10), 0.04, 0.07, 0.87]	Ne Pair 2 > 4 [4.11, 0.02, 0.29]	Ne Pair 2 < 3 [-3.23, 0.05, 0.65] Ne Pair 3 > 4 [4.11, 0.02, 0.93] Ne Pair 4 < 5 [-3.08, 0.05, 0.72]	Ne Pair 2 SCTG > CRG [3.75, 0.00, 1.44] Ne Pair 4 SCTG > CRG [3.52, 0.00, 1.36]
Gamma band	Time by Group	NS	NA	NA	NA
	Time by Condition by Group	[3.90(2), 0.03, 0.13, 0.68]	NS	NS	P SCTG > CRG 2.84, 0.03, 1.10
	Time by Pair by Group	NS	NA	NA	NA
	Time by Condition by Pair by Group	NS	NA	NA	NA

NA: not apply. NS: not significant. P: Positive condition. N: Neutral condition. Ne: Negative condition. SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group. *Post hoc* comparisons were calculated using the Index of Change [T2 (post-intervention protocol) – T1 (pre-intervention protocol)].

Figure 1. Flow diagram illustrating the steps followed during the study.

Figure 2. Trial example of experimental task. It shows a sequence example of one trial of CVT with an IAPS negative image.

Figure 1.



*Social Cognitive Training Group **Conventional Reintegration Group

Figure 2.

Supplementary data material

Neurocognitive reorganization of emotional processing following a socio-cognitive intervention in Colombian ex-combatants

Valencia, S., Trujillo, N., Trujillo, S., Acosta, A., Rodríguez, M., Ugarriza, JE., López, JD., García, AM & Parra, MA.

Supplementary table 1. Mixed ANOVA for behavioral CVT data

Factors	Mixed ANOVA
	Accuracy
Time	[F(1)=5.62, p=0.03 η2=0.26 b=0.61]
Time by Group	[F(1)=1.64, p=0.22 η2=0.09 b=0.23]
Condition	[F(2)=25.44, p=0.00 η2=0.61 b=1.00]
Condition by Group	[F(2)=4.73, p=0.02 η2=0.23 b=0.75]
Time by Condition	[F(2)=1.43, p=0.25 η2=0.08 b=0.28]
Time by Condition by Group	[F(2)=0.57, p=0.57 η2=0.03 b=0.14]
	Reaction time
Time	[F(1)=4.00, p=0.06 η2=0.19 b=0.47]
Time by Group	[F(1)=2.36, p=0.14 η2=0.12 b=0.31]
Condition	[F(4)=11.35, p=0.00 η2=0.40 b=0.99]
Condition by Group	[F(0)=1.54, p=0.23 η2=0.08 b=0.30]
Time by Condition	[F(0)=0.54, p=0.59 η2=0.03 b=0.13]
Time by Condition by Group	[F(0)=0.15, p=0.86 η2=0.01 b=0.07]
	Error type
Time	[F(1)=9.47, p=0.01 η2=0.28 b=0.84]
Time by Group	[F(1)=2.78, p=0.11 η2=0.10 b=0.36]
Error type	[F(5)=35.95, p=0.00 η2=0.60 b=1.00]
Error type by Group	[F(5)=1.38, p=0.24 η2=0.05 b=0.47]
Time by Error type	[F(5)=3.83, p=0.00 η2=0.14 b=0.93]
Time by Error type by Group	[F(5)=1.27, p=0.28 η2=0.05 b=0.44]

Supplementary table* 2. *Means and standard deviations of brain connectivity values across Groups, Times, Conditions and ROI Pairs.

Delta band	**SCTG M (SD)**						**CRG M (SD)**					
	T1			**T2**			**T1**			**T2**		
	Positive	**Neutral**	**Negative**	**Positive**	**Neutral**	**Negative**	**Positive**	**Neutral**	**Negative**	**Positive**	**Neutral**	**Negative**
Pair 1	0.014 (0.006)	0.020 (0.009)	0.013 (0.006)	0.017 (0.008)	0.015 (0.008)	0.016 (0.011)	0.016 (0.011)	0.015 (0.007)	0.013 (0.006)	0.013 (0.006)	0.018 (0.009)	0.013 (0.008)
Pair 2	0.020 (0.015)	0.019 (0.011)	0.018 (0.011)	0.023 (0.016)	0.028 (0.014)	0.040 (0.022)	0.015 (0.006)	0.022 (0.015)	0.022 (0.013)	0.017 (0.011)	0.018 (0.015)	0.016 (0.008)
Pair 3	0.022 (0.015)	0.023 (0.016)	0.023 (0.015)	0.022 (0.015)	0.026 (0.012)	0.034 (0.016)	0.019 (0.008)	0.023 (0.018)	0.020 (0.016)	0.023 (0.019)	0.025 (0.018)	0.024 (0.019)
Pair 4	0.024 (0.020)	0.019 (0.009)	0.019 (0.010)	0.022 (0.017)	0.026 (0.012)	0.034 (0.021)	0.017 (0.008)	0.020 (0.015)	0.023 (0.012)	0.016 (0.010)	0.017 (0.014)	0.013 (0.006)
Pair 5	0.027 (0.023)	0.021 (0.014)	0.024 (0.017)	0.020 (0.012)	0.026 (0.012)	0.032 (0.016)	0.022 (0.010)	0.023 (0.019)	0.022 (0.016)	0.022 (0.019)	0.026 (0.016)	0.023 (0.018)
Pair 6	0.017 (0.011)	0.017 (0.010)	0.019 (0.011)	0.022 (0.013)	0.019 (0.012)	0.024 (0.013)	0.016 (0.006)	0.018 (0.012)	0.021 (0.012)	0.028 (0.025)	0.024 (0.019)	0.021 (0.012)

Gamma band	**SCTG M (SD)**						**CRG M (SD)**					
	T1			**T2**			**T1**			**T2**		
	Positive	**Neutral**	**Negative**	**Positive**	**Neutral**	**Negative**	**Positive**	**Neutral**	**Negative**	**Positive**	**Neutral**	**Negative**
Pair 1	0.010 (0.003)	0.011 (0.005)	0.010 (0.004)	0.014 (0.011)	0.014 (0.012)	0.014 (0.014)	0.012 (0.005)	0.010 (0.003)	0.009 (0.003)	0.009 (0.002)	0.010 (0.003)	0.009 (0.002)
Pair 2	0.009 (0.004)	0.010 (0.003)	0.010 (0.004)	0.012 (0.009)	0.013 (0.009)	0.012 (0.008)	0.012 (0.008)	0.011 (0.007)	0.011 (0.007)	0.008 (0.001)	0.009 (0.003)	0.008 (0.001)
Pair 3	0.009 (0.003)	0.011 (0.004)	0.009 (0.003)	0.012 (0.011)	0.012 (0.009)	0.011 (0.011)	0.011 (0.004)	0.011 (0.004)	0.010 (0.004)	0.008 (0.002)	0.009 (0.003)	0.008 (0.001)
Pair 4	0.008 (0.003)	0.010 (0.002)	0.010 (0.004)	0.011 (0.004)	0.011 (0.003)	0.010 (0.004)	0.011 (0.007)	0.011 (0.006)	0.011 (0.007)	0.008 (0.002)	0.008 (0.002)	0.009 (0.001)
Pair 5	0.009 (0.003)	0.011 (0.004)	0.010 (0.003)	0.011 (0.006)	0.011 (0.005)	0.009 (0.002)	0.010 (0.002)	0.010 (0.004)	0.009 (0.004)	0.008 (0.001)	0.009 (0.002)	0.008 (0.001)

Pair 6	0.008 (0.002)	0.010 (0.002)	0.010 (0.002)	0.012 (0.004)	0.011 (0.004)	0.012 (0.005)	0.012 (0.004)	0.011 (0.004)	0.011 (0.005)	0.008 (0.003)	0.009 (0.002)	0.009 (0.003)

T1 (pre-intervention protocol. T2: post-intervention protocol

Supplementary table 3. Mixed ANOVA for CVT for Delta band

Factors	Mixed ANOVA
Time	[F(1)=3.84, p=0.06, η2=0.13, b=0.47]
Time by Group	[F(1)=2.45, p=0.13, η2=0.09, b=0.33]
Condition	[F(2)=1.02, p=0.37, η2=0.04, b=0.22]
Condition by Group	[F(2)=1.08, p=0.35, η2=0.04, b=0.23]
Pair	[F(5)=7.04, p=0.00, η2=0.21, b=1.00]
Pair by Group	[F(5)=1.81, p=0.11, η2=0.07, b=0.61]
Time by Condition	[F(2)=0.84, p=0.44, η2=0.03, b=0.19]
Time by Condition by Group	**[F(2)=4.18, p=0.02, η2=0.14, b=0.71]**
Time by Pair	[F(5)=1.09, p=0.37, η2=0.04, b=0.38]
Time by Pair by Group	**[F(5)=3.37, p=0.01, η2=0.11, b=0.89]**
Condition by Pair	[F(10)=1.81, p=0.06, η2=0.07, b=0.84]
Condition by Pair by Group	[F(10)=0.28, p=0.19, η2=0.07, b=0.25]
Time by Condition by Pair	[F(10)=1.84, p=0.05, η2=0.07, b=0.84]
Time by Condition by Pair by Group	**[F(10)=1.97, p=0.04, η2=0.07, b=0.87]**

Note: bold represent statistical significance for Time by Group interactions.

Supplementary table 3.1. Related t test for CVT Delta band

Pairs		SCTG	CRG
Positive	**Neutral**	**[t(14) =-10.98, q=0.00, d=-4.00]**	**[t(12) =-6.61, q=0.00, d=-2.58]**
Positive	**Negative**	**[t(14) =-3.70, q=0.00, d=-1.05]**	[t(12) =0.97, q=0.35, d=0.41]
Neutral	**Negative**	**[t(14) =10.94, q=0.00, d=3.99]**	**[t(12) =6.58, q=0.00, d=2.59]**

Note: bold represent statistical significance. SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group

Supplementary table 3.2. Independent t test for CVT Delta band averaged Pairs

	SCTG vs. CRG
Positive	[t(26) =-0.61, q=0.55, d=-0.2]
Neutral	[t(26) =1.34, q=0.29, d=-0.5]
Negative	**[t(26) =3.18, q=0.011, d=1.24]**

Supplementary table 3.3. Related t test for CVT Delta band for Pairs, averaged Conditions, and Groups separately

Pair		SCTG	CRG
1	**2**	[t(14) =-3.50, q=0.05, d=-0.55]	[t(12) =0.70, q=0.56, d=0.30]
	3	[t(14) =-1.37, q=0.35, d=-0.40]	[t(12) =-0.88, q=0.49, d=-0.41]
	4	[t(14) =-1.89, q=0.24, d=-0.50]	[t(12) =1.10, q=0.40, d=0.48]
	5	[t(14) =-0.27, q=0.85, d=-0.09]	[t(12) =-0.36, q=0.72, d=-0.16]
	6	[t(14) =-0.91, q=0.56, d=-0.27]	[t(12) =-1.37, q=0.37, d=-0.66]
2	**3**	[t(14) =1.89, q=0.24, d=0.54]	**[t(12) =-3.64, q=0.02, d=-0.60]**
	4	[t(14) =3.09, q=0.06, d=0.28]	[t(12) =1.16, q=0.40, d=0.12]
	5	[t(14) =2.20, q=0.23, d=0.68]	[t(12) =-1.73, q=0.27, d=-0.39]

	6	[t(14) =1.41, q=0.35, d=0.53]	[t(12) =-2.06, q=0.19, d=-0.81]
3	**4**	[t(14) =-0.69, q=0.66, d=-0.19]	**[t(12) =4.25, q=0.02, d=0.77]**
	5	[t(14) =1.32, q=0.35, d=0.25]	[t(12) =1.60, q=0.29, d=0.21]
	6	[t(14) =0.18, q=0.86, d=0.07]	[t(12) =-0.65, q=0.56, d=-0.22]
4	**5**	[t(14) =1.49, q=0.35, d=0.38]	[t(12) =-2.77, q=0.08, d=-0.54]
	6	[t(14) =0.64, q=0.66, d=0.23]	[t(12) =-2.39, q=0.13, d=-0.98]
5	**6**	[t(14) =-0.43, q=0.78, d=-0.16]	[t(12) =-1.15, q=0.40, d=-0.42]

Note: bold represent statistical significance. SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group.

Supplementary table 3.4. Independent t test for CVT Delta band for Pairs and Groups

Pair	SCTG vs. CRG
1	[t(26) =0.29, q=0.93, d=-0.11]
2	**[t(26) =2.93, q=0.04, d=1.11]**
3	[t(26) =0.28, q=0.93, d=0.10]
4	[t(26) =2.41, q=0.07, d=0.92]
5	[t(26) =0.08, q=0.93, d=0.03]
6	[t(26) =-0.48, q=0.93, d=-0.18]

Note: bold represent statistical significance. SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group.

Supplementary table 3.5. Related t test for CVT Delta band for Pairs and Groups separately, positive condition

Pairs		SCTG	CRG
1	**2**	[t(14) =0.40, q=0.76, d=0.09]	[t(12) =-1.16, q=0.40, d=-0.50]
	3	[t(14) =1.03, q=0.44, d=0.35]	[t(12) =-1.44, q=0.34, d=-0.54]
	4	[t(14) =1.29, q=0.41, d=0.39]	[t(12) =-0.53, q=0.70, d=-0.30]
	5	[t(14) =1.82, q=0.29, d=0.77]	[t(12) =-0.59, q=0.70, d=-0.21]
	6	[t(14) =-0.38, q=0.76, d=-0.13]	[t(12) =-2.29, q=0.28, d=-0.85]
2	**3**	[t(14) =1.19, q=0.42, d=0.26]	[t(12) =-0.78, q=0.61, d=-0.25]
	4	[t(14) =1.67, q=0.29, d=0.30]	[t(12) =1.39, q=0.34, d=0.26]
	5	[t(14) =2.17, q=0.29, d=0.69]	[t(12) =0.29, q=0.78, d=0.09]
	6	[t(14) =-0.57, q=0.72, d=-0.19]	[t(12) =-1.69, q=0.29, d=-0.62]
3	**4**	[t(14) =0.27, q=0.79, d=0.07]	[t(12) =1.35, q=0.34, d=0.40]
	5	[t(14) =2.06, q=0.29, d=0.48]	[t(12) =2.22, q=0.28, d=0.26]
	6	[t(14) =-1.10, q=0.44, d=-0.39]	[t(12) =-1.72, q=0.29, d=-0.37]
4	**5**	[t(14) =1.58, q=0.29, d=0.39]	[t(12) =-0.30, q=0.78, d=-0.07]
	6	[t(14) =-1.69, q=0.29, d=-0.42]	[t(12) =-1.95, q=0.28, d=-0.73]
5	**6**	[t(14) =-2.40, q=0.29, d=-0.74]	[t(12) =-2.02, q=0.28, d=-0.58]

SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group.

Supplementary table 3.6. Related t test for CVT Delta band for Pairs and Groups separately, neutral condition

Pairs		SCTG	CRG
1	**2**	[t(14) =-3.08, q=0.06, d=-0.94]	[t(12) =0.75, q=0.78, d=0.33]
	3	[t(14) =-2.10, q=0.20, d=-0.57]	[t(12) =0.06, q=0.99, d=0.02]
	4	[t(14) =-3.25, q=0.06, d=-0.93]	[t(12) =0.59, q=0.78, d=0.27]

	5	[t(14) =-2.69, q=0.09, d=-0.79]	[t(12) =-0.02, q=0.99, d=-0.01]
	6	[t(14) =-1.54, q=0.44, d=-0.44]	[t(12) =-0.50, q=0.78, d=-0.24]
2	**3**	[t(14) =1.30, q=0.47, d=0.38]	[t(12) =-1.44, q=0.75, d=-0.26]
	4	[t(14) =0.74, q=0.56, d=0.09]	[t(12) =-0.98, q=0.75, d=-0.06]
	5	[t(14) =0.71, q=0.56, d=0.24]	[t(12) =-1.63, q=0.75, d=-0.30]
	6	[t(14) =1.22, q=0.47, d=0.43]	[t(12) =-1.22, q=0.75, d=-0.50]
3	**4**	[t(14) =-1.07, q=0.47, d=-0.32]	[t(12) =1.14, q=0.75, d=0.20]
	5	[t(14) =-1.08, q=0.47, d=-0.17]	[t(12) =-0.47, q=0.78, d=-0.03]
	6	[t(14) =0.26, q=0.80, d=0.08]	[t(12) =-0.49, q=0.78, d=-0.20]
4	**5**	[t(14) =0.54, q=0.64, d=0.16]	[t(12) =-1.46, q=0.75, d=-0.24]
	6	[t(14) =1.05, q=0.47, d=0.37]	[t(12) =-1.04, q=0.75, d=-0.43]
5	**6**	[t(14) =0.72, q=0.56, d=0.23]	[t(12) =-0.42, q=0.75, d=-0.18]

SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group.

Supplementary table 3.7. Related t test for CVT Delta band for Pairs and Groups separately, negative condition

Pairs		**SCTG**	**CRG**
1	**2**	[t(14) =-3.17, q=0.05, d=-1.05]	[t(12) =1.32, q=0.35, d=0.48]
	3	[t(14) =-1.59, q=0.29, d=-0.63]	[t(12) =-0.86, q=0.56, d=-0.34]
	4	[t(14) =-1.97, q=0.21, d=-0.69]	[t(12) =2.16, q=0.16, d=0.85]
	5	[t(14) =-0.68, q=0.64, d=-0.28]	[t(12) =-0.28, q=0.89, d=-0.12]
	6	[t(14) =-0.30, q=0.77, d=-0.11]	[t(12) =-0.11, q=0.91, d=-0.06]
2	**3**	[t(14) =1.69, q=0.28, d=0.50]	**[t(12) =-3.23, q=0.05, d=-0.65]**
	4	**[t(14) =4.11, q=0.02, d=0.29]**	[t(12) =2.05, q=0.16, d=0.22]
	5	[t(14) =2.32, q=0.18, d=0.62]	[t(12) =-1.89, q=0.18, d=-0.46]
	6	[t(14) =2.00, q=0.21, d=0.84]	[t(12) =-1.33, q=0.35, d=-0.51]
3	**4**	[t(14) =-0.60, q=0.64, d=-0.17]	**[t(12) =4.11, q=0.02, d=0.93]**
	5	[t(14) =1.49, q=0.30, d=0.21]	[t(12) =1.21, q=0.38, d=0.17]
	6	[t(14) =1.02, q=0.44, d=0.43]	[t(12) =0.78, q=0.56, d=0.30]
4	**5**	[t(14) =1.39, q=0.31, d=0.33]	**[t(12) =-3.08, q=0.05, d=-0.72]**
	6	[t(14) =1.25, q=0.35, d=0.52]	[t(12) =-2.40, q=0.13, d=-0.89]
5	**6**	[t(14) =0.39, q=0.76, d=0.16]	[t(12) =0.22, q=0.89, d=0.08]

Note: bold represent statistical significance. SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group.

Supplementary table 3.8. Independent t test for CVT Delta band for Pairs across Groups Conditions separately

Pairs	**Positive**	**Neutral**	**Negative**
1	[t(26)=1.63, q=0.58, d=0.62]	[t(26)=-1.50, q=0.36, d=-0.56]	[t(26)=0.86, q=0.42, d=0.33]
2	[t(26)=0.26, q=0.88, d=0.10]	[t(26)=1.67, q=0.36, d=0.62]	**[t(26)=3.75, q=0.00, d=1.44]**
3	[t(26)=-0.96, q=0.58, d=-0.36]	[t(26)=0.12, q=0.91, d=0.04]	[t(26)=1.21, q=0.42, d=0.46]
4	[t(26)=-0.15, q=0.88, d=-0.06]	[t(26)=1.38, q=0.36, d=0.52]	**[t(26)=3.52, q=0.00, d=1.36]**
5	[t(26)=-1.19, q=0.58, d=-0.45]	[t(26)=0.40, q=0.83, d=0.14]	[t(26)=0.87, q=0.42, d=0.33]
6	[t(26)=-0.88, q=0.58, d=-0.33]	[t(26)=-0.69, q=0.74, d=-0.27]	[t(26)=0.81, q=0.42, d=0.32]

Note: bold represent statistical significance.

Supplementary table 4. Mixed ANOVA for CVT for Theta band

Factors	Mixed ANOVA
Time	[F(1)=3.60, p=0.07, η2=0.12, b=0.45]
Time by Group	[F(1)=0.03, p=0.87, η2=0.00, b=0.05]
Condition	[F(2)=0.04, p=0.96, η2=0.00, b=0.06]
Condition by Group	[F(2)=0.46, p=0.63, η2=0.02, b=0.12]
Pair	[F(5)=4.49, p=0.00, η2=0.15, b=0.97]
Pair by Group	[F(5)=0.96, p=0.45, η2=0.04, b=0.33]
Time by Condition	[F(2)=1.56, p=0.22, η2=0.06, b=0.32]
Time by Condition by Group	[F(2)=0.07, p=0.93, η2=0.00, b=0.06]
Time by Pair	[F(5)=1.00, p=0.42, η2=0.04, b=0.35]
Time by Pair by Group	[F(5)=0.48, p=0.79, η2=0.02, b=0.18]
Condition by Pair	[F(10)=0.44, p=0.93, η2=0.02, b=0.23]
Condition by Pair by Group	[F(10)=1.06, p=0.39, η2=0.04, b=0.56]
Time by Condition by Pair	[F(10)=0.79, p=0.64, η2=0.03, b=0.41]
Time by Condition by Pair by Group	[F(10)=0.71, p=0.71, η2=0.03, b=0.37]

Supplementary table 5. Mixed ANOVA for CVT for Alpha band

Factors	Mixed ANOVA
Time	[F(1)=0.00, p=0.97, η2=0.00, b=0.05]
Time by Group	[F(1)=0.08, p=0.78, η2=0.00, b=0.06]
Condition	[F(2)=3.12, p=0.05, η2=0.11, b=0.57]
Condition by Group	[F(2)=0.26, p=0.77, η2=0.01, b=0.09]
Pair	[F(5)=6.97, p=0.00, η2=0.21, b=1.00]
Pair by Group	[F(5)=1.39, p=0.23, η2=0.05, b=0.48]
Time by Condition	[F(2)=0.37, p=0.69, η2=0.01, b=0.11]
Time by Condition by Group	[F(2)=1.16, p=0.32, η2=0.04, b=0.24]
Time by Pair	[F(5)=0.62, p=0.68, η2=0.02, b=0.22]
Time by Pair by Group	[F(5)=0.98, p=0.43, η2=0.04, b=0.34]
Condition by Pair	[F(10)=0.67, p=0.75, η2=0.03, b=0.35]
Condition by Pair by Group	[F(10)=0.85, p=0.58, η2=0.03, b=0.45]
Time by Condition by Pair	[F(10)=0.98, p=0.46, η2=0.04, b=0.52]
Time by Condition by Pair by Group	[F(10)=0.91, p=0.53, η2=0.03, b=0.48]

Supplementary table 6. Mixed ANOVA for CVT for Beta band

Factors	Mixed ANOVA
Time	[F(1)=9.32, p=0.01, η2=0.26, b=0.84]
Time by Group	[F(1)=0.03, p=0.86, η2=0.00, b=0.05]
Condition	[F(2)=1.31, p=0.28, η2=0.05, b=0.27]
Condition by Group	[F(2)=0.15, p=0.86, η2=0.01, b=0.07]
Pair	[F(5)=1.08, p=0.37, η2=0.04, b=0.38]
Pair by Group	[F(5)=0.43, p=0.83, η2=0.02, b=0.16]
Time by Condition	[F(2)=0.11, p=0.90, η2=0.00, b=0.07]
Time by Condition by Group	[F(2)=1.73, p=0.19, η2=0.06, b=0.35]

Time by Pair	[F(5)=0.89, p=0.49, η2=0.03, b=0.31]
Time by Pair by Group	[F(5)=0.70, p=0.62, η2=0.03, b=0.25]
Condition by Pair	[F(10)=2.21, p=0.02, η2=0.08, b=0.91]
Condition by Pair by Group	[F(10)=0.97, p=0.47, η2=0.04, b=0.51]
Time by Condition by Pair	[F(10)=1.05, p=0.40, η2=0.04, b=0.55]
Time by Condition by Pair by Group	[F(10)=0.95, p=0.48, η2=0.04, b=0.50]

Supplementary table 7. Mixed ANOVA for CVT for Gamma band

Factors	**Mixed ANOVA**
Time	[F(1)=0.01, p=0.91, η2=0.00, b=0.05]
Time by Group	[F(1)=3.86, p=0.06, η2=0.13, b=0.47]
Condition	[F(2)=1.43, p=0.25, η2=0.05, b=0.29]
Condition by Group	[F(2)=0.87, p=0.42, η2=0.03, b=0.19]
Pair	[F(5)=1.07, p=0.38, η2=0.04, b=0.37]
Pair by Group	[F(5)=0.77, p=0.57, η2=0.03, b=0.27]
Time by Condition	[F(2)=0.08, p=0.92, η2=0.00, b=0.06]
Time by Condition by Group	**[F(2)=3.90, p=0.03, η2=0.13, b=0.68]**
Time by Pair	[F(5)=0.63, p=0.68, η2=0.02, b=0.22]
Time by Pair by Group	[F(5)=0.75, p=0.59, η2=0.03, b=0.26]
Condition by Pair	[F(10)=1.47, p=0.15, η2=0.05, b=0.73]
Condition by Pair by Group	[F(10)=0.48, p=0.90, η2=0.02, b=0.25]
Time by Condition by Pair	[F(10)=1.00, p=0.44, η2=0.04, b=0.52]
Time by Condition by Pair by Group	[F(10)=0.54, p=0.86, η2=0.02, b=0.28]

Note: bold represent statistical significance.

Supplementary table 7.1. Related t test for CVT Gamma band

Pairs		**SCTG**	**CRG**
Positive	**Neutral**	[t(14)=2.01, q=0.11, d=0.23]	[t(12)=-1.60, q=0.20, d=-0.36]
Positive	**Negative**	[t(14)=1.93, q=0.11, d=0.22]	[t(12)=-1.63, q=0.20, d=-0.26]
Neutral	**Negative**	[t(14)=0.00, q=1.00, d=0.00]	[t(12)=0.45, q=0.66, d=0.07]

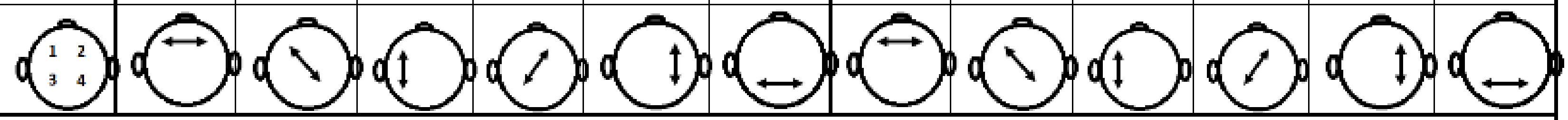
Note: bold represent statistical significance. SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group.

Supplementary table 7.2. Independent t test for CVT Gamma band

Condition	**SCTG vs CRG**
Positive	**[t(26)=2.84, q=0.03, d=1.10]**
Neutral	[t(26)=1.44, q=0.17, d=0.56]
Negative	[t(26)=1.42, q=0.17, d=0.54]

Note: bold represent statistical significance. SCTG: Social Cognitive Training Group. CRG: Conventional Reintegration Group.

Supplementary table 8. Summary of significant contrasts revealed by post-hoc tests carried our across Groups, Times, Conditions and ROI Pairs.

		SCTG						**CRG**					
	ROI/Pairs	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
													
Delta	**Within-Subjects**												
	Positive												
	Neutral												
	Negative												
	Between-Subjects												
	Positive												
	Neutral												
	Negative												
Gamma	**Within-Subjects**												
	Positive												
	Neutral												
	Negative												
	Between-Subjects												
	Positive												
	Neutral												
	Negative												

Highlighted Cells denote FDR-corrected significant contrasts within (upper) or between-subjects (lower)