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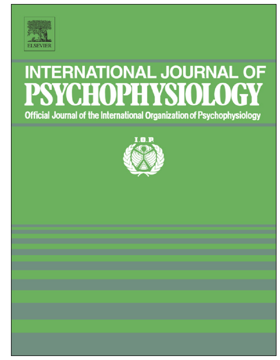

Emotion regulation in adolescents: Influences of internal representations of relationships – An ERP study

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Running Head:
Emotion Regulation and Internal Representations

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Abstract

Emotion regulation (ER) strategies can decrease the intensity or modify the experience of emotions. Deficits in emotion regulation are implicated in a wide range of psychopathologies. It is argued that interpersonal, socio-cognitive, and developmental variables play an important role in ER. This is the first study to explore the contribution of individual differences in internal representations of relationships (IRR) to neural correlates of ER in a sample of adolescents. Event related potentials of 53 adolescents (12 to 17 years old) were collected while performing an ER task. IRR was assessed with the social cognition and object relations scale (SCORS-G; Westen, 1995) coding of narratives from interviews. Results show that individual differences in IRR significantly predicted the modulation of emotional responses by expressive suppression in adolescents, accounting for 48% of the variance of changes in occipital late positive potentials (LPP). Thus, it appears that IRR are implicated in an individual's ability to regulate emotions. The clinical implications of the findings are discussed.

Keywords: late positive potential, response modulation, expressive suppression, internal working model, object relations

1. Introduction

Emotion regulation (ER) refers to the ability to modify emotional experience and expression (Gross & Thompson, 2007; McRae & Gross, 2020) and is widely researched in adults and children (Allen & Windsor, 2019; Compas et al., 2017; Dryman & Heimberg, 2018). Adaptive ER predicts positive outcomes in mental health, physical, and social domains (Aldao, Gee, De Los Reyes, & Seager, 2016; Berking, Wirtz, Svaldi, & Hofmann, 2014; Cole, Hall & Hajal, 2017; Cludius Mennin & Ehring, 2020; Compas et al., 2017; Kircanski et al., 2018; Klemanski, Curtiss, McLaughlin & Nolen-Hoeksema, 2017; Lopez, Luby, Belden, & Barch, 2018; McRae & Gross, 2020; Schäfer, Naumann, Holmes, Tuschen-Caffier, & Samson, 2017; Taylor, Moulding, & Nedeljkovic, 2018).

Adolescence is a critical biopsychosocial developmental period (Casey, 2015; Dahl, Allen, Wilbrecht & Suleimani, 2018) that brings about ER maturation and refinement (Gresham & Gullone, 2012; Lennarz, Hollenstein, Lichtwarck-Aschoff, Kuntsche & Granic, 2019; Penela, Walker, Degnan, Fox, & Henderson, 2015; Schweizer, Gotlib, & Blakemore, 2020; Shulman, Harden, Chein & Steinberg, 2016; Silvers et al., 2012; Zimmermann & Iwanski, 2014). In addition, adolescents experience a wide range of new interpersonal contexts (peer, romantic, competitive) and growth in social-cognitive skills (e.g., perspective-taking, mentalizing; Kilford, Garrett & Blakemore, 2016).

The current challenges in ER research include a better understanding of the contribution of social (e.g. relationships) and developmental (e.g. age) factors (Barthel, Hay, Doan & Hofmann, 2018; McRae & Gross, 2020; Lindsey, 2020; Mikulincer & Shaver, 2019). Furthermore, there is a relative dearth of experimental ER research assessing neural dynamics in adolescents. Consequently, the present study focuses on individual differences in internal representations of relationships and the neural correlates of ER in adolescents.

1.1. ER Dynamics and Strategies

ER consists of "intrinsic and extrinsic processes for monitoring, evaluating, and modifying emotional reactions to accomplish one's goals" (Thompson, 1994, p.27-28;). ER dynamics and strategies vary in terms of when they are deployed (e.g., before or after a situation), their specific impact on emotional experience and expression (e.g., less negative affect), and their dependence on others (e.g., extrinsic ER, social support). Some research (McRae & Gross, 2020) suggests that certain ER strategies (reappraisal) are more adaptive in the context of mental health than others (suppression). There is however a growing recognition (Gross & Cassidy, 2019) that the extent to which a particular ER strategy is adaptive is largely context dependant (e.g. social roles, cultural norms) (De France, Lennarz, Kindt, & Hollenstein, 2018; English, Lee, John, & Gross, 2017; Imburgio & MacNamara, 2019; Kraus & Kitiyama, 2019; Kobylińska & Kusev, 2019; Lu, William, Qiao, & Xie, 2018; McRae & Gross, 2020; Paul, Simon, Kniesche, Kathmann, & Endrass, 2013; Zimmermann & Iwanski, 2014).

1.2. Electrophysiological Correlates of Emotion Regulation

Most event-related potential (ERP) studies of ER have focused on the late positive potential (LPP; Hajcak, MacNamara, & Olvet, 2010; Thom, et al., 2014), an occipital-parietal ERP observable ~300 ms following stimulus onset and typically lasting several hundred milliseconds (Foti, Hajcak, & Dien, 2009; Hajcak et al., 2010). The LPP is sensitive to emotional versus neutral images (Kujawa, Klein, & Hajcak, 2012) and to the deployment of ER strategies while viewing such images, including reappraisal (Foti & Hajcak, 2008), distraction (Uusberg, Thiruchselvam, & Gross,

2014) and suppression (Paul et al., 2013). The use of these strategies has generally been shown to decrease LPP, for instance Paul and colleagues (2013) had found suppression, reappraisal, and distraction strategies all decreasing LPP.

Further, there is some evidence that different ER strategies modulate LPP at distinct time points. Distraction (Paul et al., 2013; Thiruchselvam, Blechert, Sheppes, Rydstrom & Gross, 2011), expressive suppression (Paul et al., 2013), and cognitive suppression (Moser, Hajcak, Bukay & Simons, 2006) tend to influence earlier LPP time points, whereas cognitive reappraisal appears to influence later LPP time points (Paul et al., 2013; Thiruchselvam et al., 2011). In addition, in line with this report's theme regarding the influence of social relationships in ER (Barthel et al., 2018; Mikulincer & Shaver, 2019), several studies have shown the LPP during ER is also sensitive to social factors. Reappraisal-induced LPP reductions in 5 to 7-year olds were greatest when a parent was present or had provided ER instructions (Myrusuki et al., 2019), and suppression-induced LPP reductions were greater for Asian-Americans with a higher importance of others in one's self-concept (Kraus & Kitiyama, 2019).

There is limited amount of ERP research on ER in children, however, findings have largely been in line with research in adult populations (Lewis, Lamm, Segalowitz, Stieben & Zelazo, 2006). Child LPP amplitudes are enhanced in response to emotional versus neutral images, are modulated by ER strategies (Hajcak & Dennis, 2009; Kujawa, Klein, & Proudfit, 2013), and are test-rest reliable (Pegg et al., 2019). To date there are few LPP studies of ER in adolescents; these show that the LPP is modulated by the use of ER strategies of distraction (Zhang et al., 2014) and expressive suppression (Desatnik et al., 2017).

The above findings confirm that the LPP is an effective tool to examine neuropsychological processes related to emotion regulation, and relationship cognition in adolescents.

1.3 Individual Differences in Emotional Regulation

ER capacity relies on the interaction of multiple cortical and subcortical systems, forming a unique interactive matrix that supports a range of strategies (Thompson, Lewis & Calkins., 2008); this circuitry forms the basis of individual differences in regulation capacity (Doré, Silvers & Ochsner, 2016). Recent research has focused on the various factors that influence how an individual regulates their emotions, including personality traits and genetic predispositions (Cho, White, Yang, & Soto, 2019; Gross & John, 2003; John & Gross, 2004; Zhang et al., 2019); gender and age (Nolen-Hoeksema & Aldao, 2011); and psychopathology (Aldao, Nolen-Hoeksema, & Schweizer, 2010).

As per the current call for ER research on social and developmental factors (Barthel et al., 2018; Lindsey, 2020; McRae & Gross, 2020; Mikulincer & Shaver, 2019) this report focuses on internal representations of relationships (IRR). IRR are mental structures and tendencies, which develop through interactions between developmental experiences and dispositions (Blatt, 2004; Kernberg & Caligor, 2005). IRR are referenced in attachment (internal working models: Bowlby, 1969; Milkulincer & Shaver, 2019), social cognition (relational schemas: Johnson et al., 2010) and object relations (internal objects: Kernberg, 1982; Westen, 1991) theories. Westen (1995) integrated the above constructs of internalised representations into the social cognition and object relations scale (SCORS-G), which we utilised in the present study to measure IRR.

IRR develop during childhood via parent-child interactions and are thought to contribute to ER throughout development. In brief, during infancy and childhood caregivers help regulate the child's states and behaviours (e.g., extrinsic ER; Cole, Martin & Dennis, 2004). Gradually, regulation becomes more intrinsic as repeated interpersonal patterns consolidate into IRR. For example, the helpful extrinsic response of a caregiver, which successfully manages distress, may be internalised by the child and used for their own intrinsic ER (Fonagy, Gergely & Jurist, 2003). After developing early in life, IRR are considered to have a lifelong impact on ER, personality and relationships (Blatt & Ford, 1994; Esbjorn, Bender, Reinholdt-Dunne, Munck, & Ollendick, 2012; Garnefski, Kraaij, & van Etten, 2005; Huprich, Nelson, Paggeot, Lengu, & Albright, 2017; Johnson et al., 2010). Impairments in IRR are linked to deficits in ER and deficits in both are linked to psychiatric disorders and maladaptive behaviours (Bender, Morey, & Skodol, 2011; Haggerty et al., 2018; Lewis et al., 2016; Morey et al., 2011; Tackett, Balsis, Oltmanns, & Krueger, 2009).

Despite these overlaps and interconnections, ER and IRR are often conceptualized and studied differently, reflecting somewhat disparate sub-fields within psychology research. ER as conceptualized in this study is a multi-level cascade of cognitive processes, emerging from work on autonomic and affective regulation (Gross & Levenson, 1997), and is considered an important aspect in cognitive-affective neuroscience. In contrast, IRR has received relatively less experimental attention and is a broader interdisciplinary construct that has roots in socio-cognitive, developmental and psychodynamic theories (Johnson et al., 2010; Milkulincer & Shaver, 2019; Westen, 1991). To summarize, in the current study we consider ER to be a complex set of processes indexed partly via the LPP, and we consider IRR to reflect trait levels of ER and ER-related factors (e.g., childhood development of ER, and quality and maturity of social cognition etc).

1.4. Aims of the Present Study

Previous adolescent studies have linked neural responses elicited by emotion processing and individual differences in interpersonal functioning (Forbes et al., 2010; Pfeifer et al., 2011; Yang et al., 2007; Zilber, Goldstein & Mikulincer, 2007). However, to our knowledge there have been no reports regarding the links between IRR and the neural correlates of ER in adolescent populations. Thus, the aim of this study was to examine whether individual differences in IRR are related to neural dynamics associated with ER, specifically with expressive suppression. One primary assumption made here is that LPP reductions (neural variable) are an indirect but valid index of the engagement in ER (unobserved cognition and affect) and associated with one's trait levels of ER (Myruski et al., 2019b). We hypothesized that IRR would predict LPP decreases induced by expressive suppression, in a sample of adolescents we have previously reported on (Desiatnik et al., 2017). Specifically, we hypothesized that more mature (higher) IRR would facilitate more efficient ER indicated by greater LPP decreases to negative stimuli, as compared to neutral and no-regulation viewing.

Further, although all of the IRR factors measured by SCORS-G are theoretically related to ER capacity, they are distinct (see Methods section for details) and are likely to be differentially implicated in various ER strategies and contexts. Therefore, it was of interest to explore which of the different IRR factors were specifically implicated in expressive suppression.

2. Materials and Methods

2.1. Participants

Participants were fifty-three 12-17-year-old adolescents (M = 14.43 years, SD = 1.74); 29 females and 24 males. There were seventeen 12-13-year-olds, twenty 14-15-year-olds and sixteen 16-17-year-olds. The participants were recruited from a diverse community in North West London. All participants were proficient in English for a minimum of five years, right-handed with no chronic illnesses, had normal/corrected to normal vision, and had no history of drug or alcohol dependency or diagnosed psychopathology. Participants received 20 GBP as remuneration for their participation.

2.2. Procedure

Informed written consent and assent was obtained from the parents and adolescents participating in this study prior to the commencement of any study procedures. The study was approved by the UCL Research Ethics Committee (UCL Ethics Project ID Number: 1908/001). After an introduction to the study, EEG sensors were applied, and participants were given detailed instructions. The EEG task consisted of 2 blocks. Block 1 (passive view): 30 unpleasant and 30 neutral image trials presented randomly, to establish the effect of emotional valence on the LPP. Block 1 was followed by expressive suppression (ES) instructions: participants were instructed not to show their feelings, so that someone watching them would have no idea what they were feeling. Participants were shown cameras at the bottom of the computer screen and informed that experimenters would be watching their responses. Participants were asked to repeat what was required of them in the task. Prior to the EEG recording, participants completed 3 trials, which they were allowed to repeat if they wished to, in order to become more comfortable with the task. Once participants confirmed they understood the task instructions, they were presented with Block 2 (ES) where they viewed 30 unpleasant images while engaged in ES. Block 1 and 2 were not counterbalanced so as to avoid the potential reduction in suppression and carryover effect that may occur as a result of placing suppression prior to passive viewing (Musser et al., 2011). After the final block the EEG sensor net was removed. All participants confirmed they had tried to make sure the experimenters could not see what they felt (For more details see Desatnik et.al, 2017). After the EEG task participants were led to another room where a different researcher conducted and audio-recorded the interview based on the Early Memory (EM) protocol (see below). Interviews lasted 20 to 40 minutes depending on individual pace and the richness of details provided. Participants were then paid and debriefed. The study data (single-subject ERP channel-of-interest estimates and IRR scores) has been uploaded to the Open Science Framework (osf.io/qq5b9; DOI:10.17605/OSF.IO/GQ5B9).

2.3. Measures

Early memory protocol (Fowler, Hilsenroth, & Handler, 1995) consists of eight queries including: earliest memory (EM); second EM; EM of mother; EM of father; EM of the first day at school; EM of feeling warm and snug; EM of a special object. It is suggested that enquiring into multiple EMs allows for a broader and more representative sample of relational experiences and internal representations of relationships. The resulting responses were transcribed and coded using the SCORS-G.

Social cognition and object relations scale - global rating (SCORS-G) (Stein & Slavin-Mulford, 2017; Westen, 1995) is a rating system designed to evaluate self and significant other representations on eight variables stemming from social cognition, attachment and object relational theories. Each variable is scored on a 7-point scale in which low scores (1-3) indicate more immature or pathological representations, while higher scores (4-7) indicate more mature and adaptive responses. These variables include:

- *Complexity of representations of people* (COM): self/other internal states; relational boundaries; integration of both positive and negative aspects of the self/others.
- *Affective quality of representations* (AFF): expectations from others within current and past relationships.
- *Emotional investment in relationships* (EIR): intimacy and emotional sharing.
- *Emotional investment in values and moral standards* (EIM): morality and compassion towards others.
- *Understanding of social causality* (SC): logic, motivation and causality of human behaviour.
- *Experience and management of aggressive impulses* (AGG): manage and tolerate experiences of aggression. .
- *Self-esteem* (SE) assesses the self-concept.
- *Identity and coherence of self (*ICS): level of fragmentation and integration.

Details about SCORS-G variables and rating methods are provided in Stein & Slavin-Mulford, 2017. The SCORS-G has been widely used in the fields of personality assessment (Siefert et al., 2018; Stein et al., 2018) and psychotherapy process and outcome (Peters, Hilsenroth, Eudell-Simmons, Blagys & Handler, 2006) to assess quality of internal representations (Mullin, Hilsenroth, Gold, & Farber, 2017), predict psychotherapy attendance and therapeutic alliance and change

(Mullin, Hilsenroth, Gold & Farber, 2018; Mullin et al., 2017; Porcerelli et al., 2006).The SCORS-G has shown good to excellent inter-rater reliability across many studies and several populations (Ackerman, Clemence, Weatherill & Hilsenroth, 1999; Fowler, Hilsenroth, & Handler, 1998; Fowler et al., 2004; Richardson, Porcerelli, Dauphin, Morris & Murdoch, 2018), as well as construct validity and predictive utility (Ackerman et al., 1999; Ackerman, Hilsenroth, Clemence, Weatherill, & Fowler, 2001; Conklin, Bradley, & Westen, 2006; Peters, 2006; Stein, Pinsker-Aspen, & Hilsenroth, 2007; Stein, Hilsenroth, Slavin-Mulford, & Pinsker, 2011; Stein et al., 2015; Stein et al., 2018).

EM narratives were transcribed, de-identified, and scored by four raters using the SCORS-G. Prior to rating the narrative data of the current study, the raters underwent supervised training in the use of the SCORS-G (Stein and Slavin-Mulford, 2017) by rating multiple early memory narratives provided in the manual (not from the sample used in this study). Subsequently the raters were evaluated for reliability on the SCORS-G. As suggested in the manual the raters were only able to score the early memory narratives used in this study once achieved good (>.60) to excellent (≥0.75) inter-rater reliability (Shrout & Fleiss, 1979) on the training narratives provided in the manual. The interrater reliability between the raters on the narratives used in the study was calculated using ICC 1 and Spearman Brown corrected one-way random effects model (1, 2). Shrout and Fleiss (1979) report the magnitude for interpreting ICC values in which poor is < .40, fair = .40 to .59, good = .60 to .74, and excellent = ≥0.75) ICCs were used to calculate reliability on early memory narratives for the raters. The ICC model 1 for AFF, EIR, and SC fell in the “excellent” range with ratings of .82, .77, and .75 respectively. While COM, EIM, AGG, SE and ICS fell in the “good” range with ratings of .71, .69,. 65,. 60 and .66 respectively. The

Spearman-Brown Model (1, 2) ICC corrected values fell in the ‘‘excellent’’ range for the COM, AFF, EIR, EIM and SC , .75, .89, .84, .79 and .80 respectively and in “good” range for AGG, SE and ICS, .70, .65, .72.

Overall the variables used in the current study were reliable. The SCORS-G data were not normally distributed; thus, the eight variables were divided into two groups of low and high, based on a median split in line with the protocol suggested in the manual by Stein, Siefert, Stewart, & Hilsenroth, 2011.

2.4. Stimuli

Stimuli were presented on a black background of a 15-inch computer monitor using Eprime 2.0 software. 30 neutral images were selected from the International Affective Picture System (IAPS) (Lang, Bradley & Cuthbert, 1997). However, IAPS images were originally developed for adults and as such, the negative images are not appropriate for use with children. Thus, 60 unpleasant developmentally appropriate negative images were drawn from the web so as to have images that are not as intensely negatively valenced and arousing as those from IAPS. All images have been uploaded to the study’s online repository which can be found at: osf.io/gq5b9; DOI 10.17605/OSF.IO/GQ5B9. 9 x 7 cm images were presented at the centre of the screen at a 65cm viewing distance. Each image covered the horizontal visual angle of 7.9° and vertical visual angle of 6.1°.

2.5. Task

Each trial in Block 1 began with a white fixation cross that appeared at the centre of the screen for 500 ms, followed by a 500 ms blank screen after which the neutral and/or unpleasant IAPS image was presented for a duration of 2000 ms which was then followed by another 500 ms blank screen. The total number of trials in Block 1 was 60, with 30 in neutral and 30 in unpleasant conditions. Each trial in

Block 2 began with a white fixation cross appearing at the centre of the screen or 500 ms. This was followed by a 2000 ms window during which the words “don’t show” appeared on the screen in white on a black background accompanied by a male or female voice (alternating) saying “don’t show”. This was followed by the presentation of the unpleasant image for 2000 ms which was then followed by a 500 ms blank screen. The total number of trials in Block 2 was 30.

2.6. EEG Recording and Data Reductions

EEG recording and analysis followed the guidelines outlined in by Keil and colleagues (2014). A copy of these guidelines can be found at osf.io/gq5b9; DOI:10.17605/OSF.IO/GQ5B9. EEG was acquired at 250 Hz with 128-channel HydroCel Geodesic sensor nets (Ag/AgCl electrodes with saline-soaked sponges) and processed with Net Station 4.3 software and GES400 amplifiers (Electrical Geodesics, Eugene, OR). All channels were referenced to Cz during recording. Data was recorded at 250 Hz sampling rate and impedances were kept below 75 kΩ. Recordings included horizontal and vertical eye channels (HEOG, VEOG). After recording, each subject’s EEG was filtered with a 0.03 Hz high- pass and a 30 Hz low-pass filter. The EEG was then segmented into stimulus-locked trials (epochs) from negative 200 ms to 1500 ms relative to the stimulus onset. Channels were marked as bad (M=7, SD = 2.56, Range=3 to 12) and replaced (for all trials) through spherical spline interpolation if the fast average amplitude was greater than 200 μV, differential average amplitude was greater than 100 μV, or the channel had zero variance. Channels were replaced if they met the above criteria in more than 25% of the trials. Further artefact detection included removing trials with amplitude changes above 150 μV across an entire segment, as well as trials with amplitude deflections of >= 140 μV at eye-blink electrodes or amplitude deflections of >= 55 μV at eye electrodes. The remaining EEG epochs were then averaged to create the stimulus-locked ERPs for each subject, re-referenced to the common average (using all channels), and baseline corrected (−200 to 0 ms). For the neutral view condition, the mean number of trials was 24.88 (SD = 4.27, range = 14–30). For the negative view condition, the mean number of trials was 23.5 (SD = 4.46, range = 14–30). For the expressive suppression condition, the mean number of trials was 26.9 (SD = 3.56, range = 16–30).

Based on previous studies (Dennis & Hajcak, 2009; Hajcak & Dennis, 2009; Moser et al., 2006), the LPP was defined as the mean amplitude in three time windows following stimulus onset: the early (350 to 600 ms), middle (600 to 1000 ms) and late (1000 to 1500 ms) time windows. Recordings were taken from three sites along the midline, where emotion regulation-related LPP activity has been previously reported: central parietal (CPz), parietal (Pz) and occipital (Oz) (cf. Desatnik et al., 2017 for more details). While the choice of Oz is unusual based on adult studies (Moser et al., 2006), it was selected for this study due to the LPP-like effects reported in children at occipital electrodes (e.g., Mulligan, Infantolino, Klein & Hajcak, 2019).

3. Results

3.1 ERP Results

Table 1 reports descriptive statistics for LPP amplitudes observed at Pz and Oz recording sites, for early, middle, and late time windows, across all three conditions:

Negative, Neutral, and Expressive Suppression (ES) (See **Fig 1.** for LPP amplitudes and scalp topography).

A 3 (Channel: CPz, Pz, Oz) x 3 (Time window: early [350-600 ms], middle [600-1000 ms], late [1000-1500 ms]) x 3 (Condition: neutral view, negative view, expressive suppression) repeated measures analysis of variance (ANOVA) identified significant main effects (Bonferroni-corrected) of: channel $F(2, 51) = 31.4$, $p < .001$, $\eta 2p = .552$; time window $F(2, 51) = 84.32$, $p < .001$, $\eta 2p = .768$; and condition $F(2, 51) = 14.58$, $p < .001$, $\eta 2p = .364$. There were significant interactions of: condition and time window $F(4, 49)=27.12$, $p < .001$, $\eta 2p = .688$; condition and channel $F(4, 49) = 22.15$, $p < .001$;, $\eta 2p = .644$, and condition, time window and channel $F(8, 45) = 10.27$, $p < .001$, $\eta 2p = .646$. The results show that the three conditions clearly differed between each other across most recording sites and time windows.

At the Oz channel, expressive suppression reduced the LPP in all three time windows compared to both neutral and negative view. The three conditions differed from one another in both early and middle time windows. In the late time window, there was no difference in LPP between neutral and negative view, whereas expressive suppression LPP remained lower than the other two.

Table 1. Mean values and standard deviations (*SD*) for LPP amplitudes for Neutral, Negative, and Expressive Suppression (ES) conditions, for every time window at CPz, Pz and Oz recording sites.

Time Window	Cpz			Pz			Oz		
(ms)	Neutral	Negative	Expressive Suppression	Neutral	Negative	Expressive Suppression	Neutral	Negative	Expressive Suppression
350 – 600	-4.51 (*6.3*)	-3.82 (*6.02*)	3.16* (*4.42*)	5.14* (*5.5*)	7.57* (*6.83*)	10.96* (*5.55*)	14.84* (*8.89*)	16.64* (*10.96*)	12.72* (*9.07*)
600 – 1000	-0.78* (*4.59*)	1.44* (*4.26*)	4.92* (*3.70*)	3.24* (*4.27*)	7.64 (*5.88*)	6.84 (*4.97*)	8.49* (*6.76*)	11.25* (*8.45*)	5.57* (*6.11*)
1000 – 1500	-0.99* (*4.41*)	1.07* (*3.66*)	2.96* (3.*58*)	1.35*† (*3.56*)	3.41 (*4.25*)	2.06 (*3.80*)	5.02 (*5.58*)	5.41 (*6.43*)	0.93* (*4.52*)

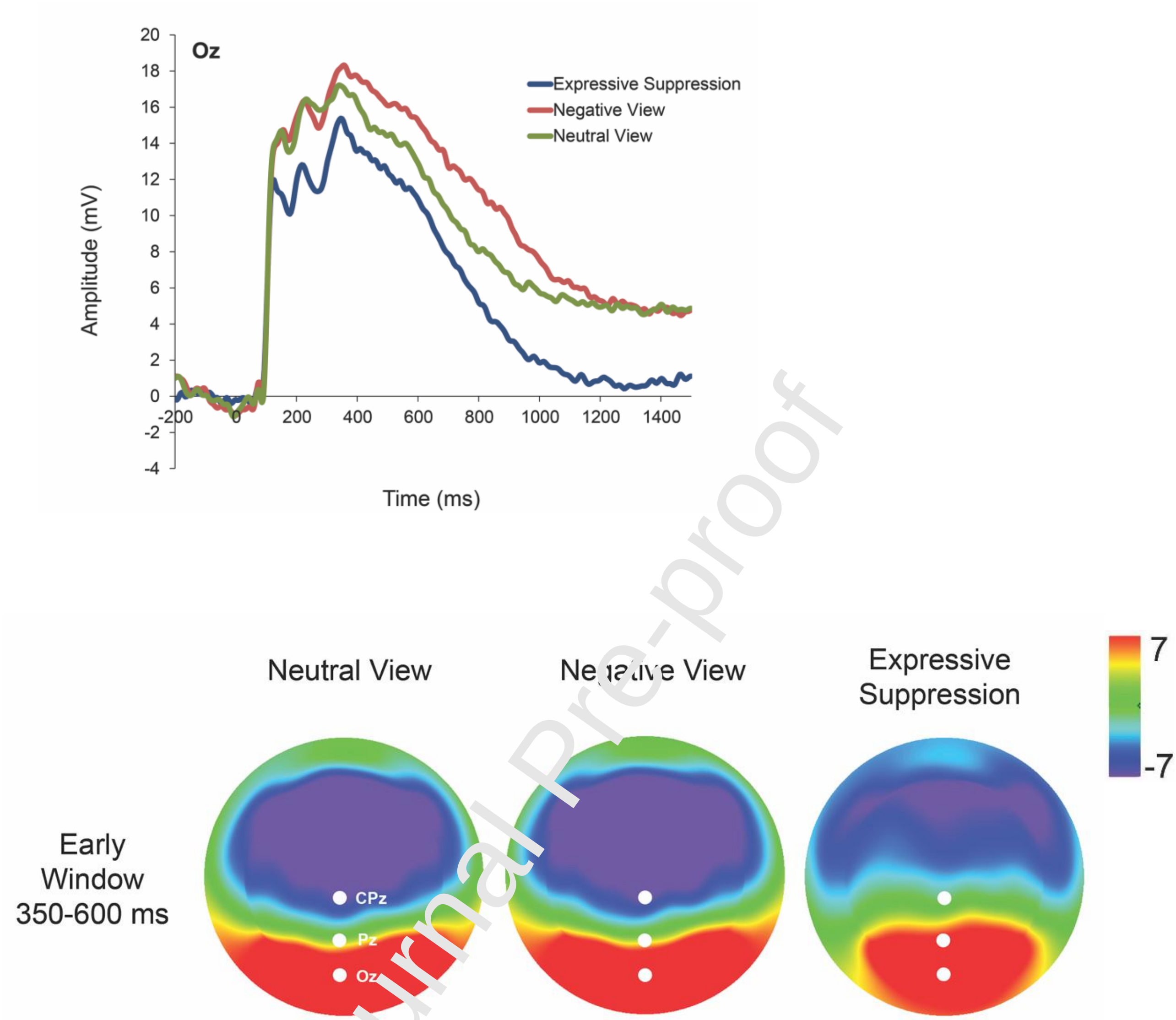

Figure 1. Stimulus-locked ERPs at Oz recording site for Expressive Suppression, Negative View, and Neutral View conditions and scalp topography for the three conditions at 350-600ms time window midpoint

Significant negative correlations with age that passed a Bonferroni correction (18 tests, adjusted p = .002) were only found for the expressive suppression condition across all time windows at the occipital (Oz) channel: early window (r = -.44, p < .001); middle window 600-1000 (r = -.45 p < .001); late window 1000-1500 (r =-.42 p < .01) Further, age was negatively correlated with expressive suppression amplitudes at Pz channel in the early time window (r = -.33, r = .015).These results suggest that LPP decreased with increasing age. Furthermore, Hotelling's t analysis showed that the correlations between age and the expressive suppression LPP at the early time window were significantly higher compared to those with the negative view LPP, t = 1.9, p < .05. This lends support to the idea that the LPP decrease associated with age was related to expressive suppression and not just the valence of the stimuli. In exploratory analyses we examined and found no significant point biserial correlations of gender with LPP values. For a detailed description and discussion of the ERP results with this sample please see Desatnik et al., (2017) or the study dataset at: osf.io/gq5b9; DOI:10.17605/OSF.IO/GQ5B9

3.2. Relationship Between SCORS-G Variables and LPP

To examine the relationship between ES and SCORS-G variables, the standard effect (negative condition) mean amplitude was subtracted from the target (ES condition) mean amplitude across Cpz, Pz and Oz recording sites, and all time windows. To determine whether SCORS-G variables predicted the LPP, a series of stepwise multiple regression tests was conducted, with the amplitudes across the Cpz, Pz and Oz recording sites as dependent variables. Age and gender were included as covariates as previous research has demonstrated significant correlations for the recording site and time windows of interest (Desiatnik et al., 2017). The results of the multiple stepwise regressions identified one significant final model for the Oz in the early time window

(R=.69, R Square =.48, F = 3.148, *p* = 0.001) (while keeping age and gender constant) which accounted for 48% of the variance predicting the LPP with the following beta weights: EIR (β=.39, *p* = 0.008); 95% CIs [1.61, 8.18], indicating a positive relationship; EIM (β=-.37, *p* = 0.016); 95% CIs [-6.24,-.88], and ICS (β=-.45, *p* = 0.004); 95% CIs [-7.26, -1.51], indicating a negative relationship (**see Table 2.).** Other variables were not significantly associated with LPP amplitude. A higher emotional investment in moral standards (EIM) and greater identity and coherence of self (ICS) predicted lower LPP, while higher emotional investment in relationships (EIR) predicted a higher LPP associated with the ES condition, while. Multiple stepwise regressions did not identify a significant model for the Cpz and Pz recording site in any time window.

Table 2. Stepwise multiple linear regression predicting the amplitude of the occipital (Oz) recording site in the early time window, based on SCORS-G variables.

	Oz 350 – 600 ms		
Variable	***Beta***	***T***	***p***
Age	.069	.508	
Gender	-.122	-.923	
COM	-.119	-.660	
AFF	.071	.445	
EIR	.483	2.800	≤.01
EIM	-.367	-2.533	≤.05
SC	-.088	-.562	
AGG	-.040	-.257	
SE	-.046	-.354	

ICS	-.463	-3.102	≤.005

Note: COM, complexity of representations of people; AFF, affective quality of representations; EIR, emotional investment in relationships; EIM, emotional investment in values and moral standards; SC, social causality; AGG, experience and management of aggressive impulses; SE, self-esteem; ICS, identity and coherence of self.

4. Discussion

The aim of the present study was to evaluate the contribution of individual differences in internal representations of relationships (IRR) to emotion regulation (ER) in a sample of community-recruited adolescents. In a previous report on this sample, expressive suppression was found to significantly modulate late positive potential (LPP) amplitude at the occipital recording site in adolescents across all time windows (Desatnik et al., 2017). The current new results provide evidence that individual differences in IRR predict neural modulation of emotional responses by expressive suppression in adolescents.

4.1. Emotion Regulation and Individual Differences

To our knowledge, this is one of the first studies to demonstrate associations between IRR and neural correlates of ER in adolescents. The current findings support our general hypothesis and indicate that individual differences in IRR account for a substantial portion, almost fifty percent, of variation in LPP dynamics. Three IRR variables were predictive of ER, as measured through occipital LPP modulation, including: emotional investment in values and moral standards (EIM), identity and coherence of self (ICS), and the emotional investment in relationships (EIR). EIM indexes genuine thoughtfulness in actions and behaviours and is associated with firmly internalised representations of significant others, which serve as a benign and flexible “moral compass”. ICS indexes perceptions of being an integrated individual with an agentive sense of self. EIR indexes emotional sharing, engagement in interpersonal relationships, and overall reliance on significant others (Westen, 1995).

The present study explored the effects of expressive suppression (Gross & Cassidy, 2019), which is considered to be an intrinsic ER strategy (Gross, 2013; Zaki

& Williams, 2013). During adolescence there is an enhanced transition from extrinsic to intrinsic ER: a continuous increase in internalized self-regulation parallels a gradual decrease in reliance on social and external regulation (Sameroff, 2010). In line with this idea, the more intrinsic or internal IRR variables (EIM and ICS) were linked with successful ER. Greater EIM and ICS predicted LPP reductions during expressive suppression, suggesting less effort and greater efficiency during ER. Adolescents with better internalised morals (EIM) and more coherent sense of self (ICS) likely expended less effort using an intrinsic ER strategy, i.e expressive suppression. This may be due to a greater habitual reliance on intrinsic ER rather than extrinsic ER (Lewis et al., 2016).

Further, ER capacity is thought to develop through initial extrinsic regulation by the caregiver (Cole et al., 2004) that is gradually internalised, resulting in the capacity for intrinsic regulation (Brant, 2014). It can be argued that a similar pathway of internalization occurs in the acquisition of moral standards. Initially, caregivers direct a child's moral values, distinguishing between right and wrong; however, gradually the child internalises these distinctions into standards that form one's individual sense of morality (Kochanska, 2002). Thus, the observed association of EIM with ER may be partially due to common developmental mechanisms. Further it may be suggested that ICS, which is associated with one's sense of agency, predicts the reduction in the LPP due to an increased sense of personal efficacy. A more integrated representation of the self may contribute to a stronger agentive sense of identity, allowing an individual to cultivate and pursue plans and goals, and be able to regulate one's own emotions more intrinsically and effortlessly (Lewis et al., 2016). In contrast, our findings indicate that higher EIR scores predicted increased LPP, which is considered to index more effort and less success in ER. Greater EIR indexes a habitual reliance on others to facilitate ER and thus, when EIR is high but extrinsic ER opportunities are few, as in this study, intrinsic ER likely required more effort.

SCORS-G variables predicted modulation of the occipital LPP only in the early time window. The early LPP is associated with attending to affective stimuli whereas the later LPP is related to subsequent semantic elaboration (Schupp, Flaisch, Stockburger, & Junghofer, 2006). The greater occipital activity noted in our study may result from initial fronto-limbic (e.g., amygdalic) over activation early during suppression trials that feeds forward to occipital regions (Anand, Grandhi, Karne & Spielberg, 2019; Goldin, McRae, Ramel & Gross, 2008; Raschle et al., 2019; Vanderhasselt, Baeken, Van Schuerbeek, Luypaert & De Raedt, 2013). One possible reason for the early occipital effects may be that during suppression, participants engaged in pre-emptive ER in anticipation of the upcoming negative stimuli. In other words, early LPP effects during suppression may be primarily associated with pre-emptive regulation of emotion perception rather than actual processing of stimulus valence or subsequent ER.

The early LPP effects also suggest that IRR predict the ability to regulate early emotion perception rather than later semantic elaboration. This may partly explain our finding that the SCORS-G variables associated with social cognition (e.g., understanding of social causality (SC), complexity of representations of people (COM)) failed to predict changes in the LPP. It is possible that social cognition would be involved in semantic elaboration of the emotion and as such, more related to different or more cognitive regulation strategies (e.g., reappraisal).

In future protocols, researchers should consider other kinds of ER in relation to IRR, as well new forms of ER tasks that involve some form of extrinsic ER (e.g., parental presence in Myruski et al., 2019a).

Deficits in both emotion perception and ER (e.g. Hu et al., 2014) as well as IRR (e.g. Bender et al., 2011) have been implicated in a wide range of psychopathologies. However, few studies to date have directly examined the relationship between ER and IRR. The findings of the current study suggest that immature, or maladaptive representations of relationships contribute to difficulties in perceiving and regulating one's negative emotions. This in turn may contribute to difficulties in interpersonal functioning observed in a number of psychiatric disorders. These ideas are consistent with those suggested in biopsychosocial (Røysamb et al., 2011; Skodol et al., 2002), and multileveled approaches to psychopathology (Huprich et al., 2017; Kozak & Cuthbert, 2016).

One can therefore argue that IRR are part of the developmental basis that facilitates the formation of more competent and effortless ER and consequently serves as a protective factor against psychopathology. This is consistent with the notion that the quality of early relationships is a significant predictor of latter psychopathology or resilience (Cicchetti & Doyle, 2016; Løkkeholt et al.,2019). Previous work that reported an association between SCORS-G variables and attachment quality (EIR in Stein et al., 2011) and therapeutic alliance (Pinsker-Aspen, Stein & Hilsenroth, 2007; EIR and ICS in Stein et al., 2007; EIR and EIM in Haggerty et al., 2018) further supports this argument. It is of interest that the same SCORS-G variables that were predictive in these past studies (EIR, EIM and ICS) were also the ones that predicted differences in ER in the current study. This raises the possibility that the LPP may be a useful biomarker indicating vulnerability to psychopathology associated with ER difficulties and the potential ability to form a therapeutic alliance.

4.2. Limitations

This study has several limitations that should be considered when interpreting the findings. Firstly, it is difficult to draw conclusions about the emotion-specific relevance of the findings because only neutral and negative stimuli were utilized, and because the impact of ER on actual felt emotion (e.g., decreased or increased negative state affect) was not assessed. In particular, here we only provided an indirect neural index of ER (LPP) and cannot be certain that a direct association between ER and IRR was shown, however, prior studies have indicated an association between suppression of the LPP and trait suppression (Myruski et al., 2019b). The study would have also benefited from a larger age range, a longitudinal design, and using more than one ER strategy. Further, in line with previous research, a counterbalanced experimental design was not used in the current study, so as to avoid the carryover effect of the ER instruction into the passive view conditions. Thus, there may have been a degree of desensitisation in participants to stimuli and consequently a potential for skewed findings. Lastly, while the IRR rating system used here is an in-depth non-self-report measure with significant advantages, it is important to be cautious in drawing conclusions about the specific nature and causality of IRR. Finally, due to the non-normal distribution of the SCORS-G data, scores were calculated using a median split as advised in the SCORS-G manual (Stein et al., 2011). Therefore, although the use of the median split with the type of data utilised in the current study is generally considered to be overall acceptable (Iacobucci, Posavac, Kardes, Schneider, & Popovich, 2015), the current data should be viewed with a degree of caution due to possible issues associated with the use of median split e.g: inflated type I error rate and reduced statistical power (Dawson & Weiss, 2012; Thoresen, 2019).

4.3. Conclusion

The present study is the first to explore the contribution of internal representations of relationships (IRR) to the neural correlates of ER in a sample of adolescents. Individual differences in IRR modulated LPP/emotional responses during expressive suppression in adolescents. It thus appears that developmental, affective and socio-cognitive variables such as IRR may be implicated in successful ER. Overall, these findings add supportive evidence for the potential of EEG biomarkers as clinically relevant constructs.

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Open Science Data:

The dataset and supplementary information for the current study can be found at: osf.io/gq5b9 (DOI:10.17605/OSF.IO/GQ5B9). The uploaded data includes single-subject ERP channel-of-interest estimates and IRR scores

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Highlights

- Emotion regulation is the ability to modify emotional experience and expression.
- Impairments in emotion regulation are implicated in a number of psychopathologies.
- A range of biopsychosocial factors influence development of emotion regulation.
- Individual personality differences predicted neural modulation of emotion response.
- Developmental factors may facilitate successful emotion regulation.
- EEG biomarkers could be used as clinically relevant constructs in the future.