Short Research Article

Real-Time Psychophysiological and Writing Correlates of Expressive Writing

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Abstract. Concealing memories and emotions associated with a traumatic event seems to have negative effects on health. Re-enacting those events through writing is an opportunity to disclose such memories and emotions, and especially for emotion regulation. To study this, 57 university students were randomly assigned to one of two groups. They either completed an expressive writing or a neutral writing task. Real-time writing and psychophysiological data were recorded throughout the experiment to examine writing dynamics associated with emotion regulation and its psychophysiological correlates (electrodermal activity and electrocardiography measures). The results showed that the expressive group (EG) paused for longer than the control group (CG) denoting a positive and medium effect size ($\eta_p^2 = .10$). Furthermore, during and after writing, the EG showed a higher low frequency/high frequency ratio than the CG, evidencing a positive and large effect size ($\eta_p^2 = .22$). These real-time findings are interpreted as signs of emotion regulation happening during writing.

Keywords: emotion regulation, expressive writing, real-time writing measures, electrodermal activity, heart rate variability

Going through a personal trauma may induce intense and long-lasting emotional effects, frequently associated with cognitive disruption, including rumination and attempts to understand what happened and why (Pennebaker & Chung, 2011). Acknowledging the emotions associated with traumatic events seems to be an important step to cope with the situation (Seeley et al., 2016). To help individuals make sense of challenging experiences, Pennebaker and Beall (1986) devised the expressive writing (EW) paradigm. This writing exercise allows people to deal with the emotions associated with traumatic memories. Numerous studies have shown the benefits of writing about traumatic events, including improved well-being and physiological functioning, and reduced symptoms in depressed and cancer patients (e.g., Frattaroli, 2006; Low et al., 2006; Seih et al., 2011).

The EW paradigm promotes the disclosure of emotional content, likely initiating a meaning-making process surrounding the stressful life event (Bourassa et al., 2017). This emotional disclosure typically leads to psychophysiological arousal, associated with short-term distress and negative mood (McGuire et al., 2005; Pennebaker et al., 1988). The negative affective arousal is the result of increased emotional expression, but ultimately outweighed by various health benefits (Frattaroli, 2006; Smyth, 1998).

Emotion regulation refers to emotional responses adequate to the context in which emotions occur, in terms of both timing and magnitude, thus facilitating adaptive emotional responses (Appelhans & Luecken, 2006). Strategies have to be put in place to achieve a desired emotional regulation goal and outcome (Gross, 2014). For instance, the goal to decrease negative emotions about an event activates strategies (e.g., escaping) that might lead to the desired outcome. In an influential model, Gross (2014) identified five possible regulation strategies: (1) situation selection, by taking actions that determine the likelihood of ending up in a situation that gives rise to the desired emotions, such as selecting a traumatic event to write about; (2) situation modification, or changing the emotional impact of a situation; (3) attentional deployment, by directing attention to change an emotion (this particular type of regulation is used when it is not possible to modify a situation); (4) cognitive change, altering the emotional significance of an event (one common form of cognitive change is reappraisal, i.e., thinking in a way that alters the emotional response); and, finally, (5) response modulation, by influencing experiential, behavioral, or physiological components of the emotional response. Perhaps the most common form of response modulation is suppression, inhibiting negative or positive expression. Both reappraisal and suppression are commonly used during emotion regulation (Gross, 2014). During EW, possibly all emotion regulation strategies might be put in place.

Concerned with promoting constructive coping after a trauma, Allen (2005) suggested that survivors of trauma should press a "pause button." The grounding behind this metaphor is that during response modulation an individual might block a dominant response to allow the reappraisal of the situation, thus better adapting to the current context. Therefore, Allen suggested that in the presence of an unbearable emotional state, two reactions are possible: (1) self-destructive behavior or (2) pausing and mentalizing. If the reaction is pausing and mentalizing, the result should be constructive coping.

Perhaps EW could be a privileged method for pausing and mentalizing. Curiously, writing logging techniques have revealed that writing is dominated by pauses and written language bursts (see Lindgren & Sullivan, 2019). Pauses are periods where writing was interrupted, typically for more than 2 s. Bursts are instances of activity between two pauses, in which at least one word was written (Alves & Limpo, 2015; Hayes & Chenoweth, 2007). Pauses are commonly interpreted as resulting from the cognitive load brought on by the demands of the writing task: the longer the pause, the heavier the load (Schilperoord, 2002). When writers encounter difficulties brought on by the demands of the task, they typically adjust their writing speed by decreasing transcription time and/or increasing pause duration (Fayol, 1999). Fayol (1999) further noticed that two mechanisms can be used to reduce this load: (1) automaticity (faster and more effortless) and (2) task combination strategies, for example, by switching attention, allowing the allocation of cognitive resources according to task demands.

Emotion regulation can be observed across all modalities of emotional responding, including behavior, thoughts, feelings (Koole, 2009), and physiological arousal (Appelhans & Luecken, 2006; Gross, 2014; Koole, 2009) of the autonomous nervous system (ANS). The two branches of the ANS – the parasympathetic nervous system (PNS) and the sympathetic nervous system (SNS) – operate on different time scales to adapt to situational challenges (Shaffer & Ginsberg, 2017). The ANS plays a critical role in regulating homeostasis (minimizing damage and maximizing functioning) and helping to deal with significant challenges (Levenson, 2014). Thus, the balance between PNS and SNS allows physiological and emotional states to meet situational demands (Appelhans & Luecken, 2006). To measure ANS dynamics, it is important to observe its functional fluctuations across an emotional experience (Kahle et al., 2016). Two widely used measures of ANS are electrodermal activity (EDA) – the variation of the electrical properties of the skin secondary to sweat secretion – and the heart rate through electrocardiography (ECG; Dawson et al., 2007). Measures of EDA and ECG represent aspects of electrodermal and cardiovascular processes that are important in emotion (Levenson, 2014). The combination of both allows measuring ANS activity in detail, since EDA reflects mostly SNS activity (Dawson et al., 2007), while ECG reflects the continuous interplay between PNS and SNS activity (Thayer et al., 2012), particularly through heart rate variability (HRV) measures (Fooken, 2017). This interplay between the PNS (vagal) and SNS has a dual influence on HR, with the former having an inhibitory influence on HR and the latter having an excitatory influence on HR. Thus, an increase in HR might imply PNS inhibition (vagal withdrawal), SNS activation, or both (Appelhans & Luecken, 2006; Berntson et al., 2007). During a situation that necessitates emotion regulation, vagal withdrawal works to support an increase in heart rate and increased attention to the environment, employing the behaviors necessary to deal with challenging situations (Perry et al., 2016).

HRV analysis is an important addition to the study of ANS since it allows for the concurrent observation of both PNS and SNS activity. Four common HRV measures are the *SD* of normal-to-normal (N–N) intervals (SDNN), the root mean square of the successive N–N interval differences (RMSSD; Camm et al., 1996), high frequency (HF), and the low frequency (LF)/HF ratio. SDNN is a measure that reflects overall autonomic modulation regardless of SNS or PNS dominance (Pichot et al., 2016). RMSSD reflects parasympathetically mediated HRV (Camm et al., 1996). The high-frequency (HF) band is thought to represent respiratory sinus arrhythmia (RSA), which is a measure of respiratory influences on autonomic control (Berntson et al., 2007). Since respiratory activity in HR is driven by the PNS, RSA is considered to reflect parasympathetic control (Berntson et al., 2007). Finally, the LF/HF ratio estimates the ratio between SNS and PNS activation and consequently sympathovagal balance (Camm et al., 1996; Malliani, 2000). This is so since variability in the LF band is driven by both branches of the ANS (Berntson et al., 2007). Many have interpreted an increase in the LF/HF ratio as an indicative of increased SNS activity (Berntson et al., 2007). However, since there is a presence of vagal activity in the LF band, it has been suggested that the LF/HF ratio should be interpreted as a conjunction of LF and HF (Camm et al., 1996; Friedman & Thayer, 1998; Malliani, 2000; Stein et al., 1996). During self-regulation, the activity of the PNS and SNS is in dynamic balance, with patterns of organized variability in HR, rather than static levels, being preserved in the face of changing environmental demands (Friedman & Thayer, 1998). Therefore, higher HRV is usually associated with the ability to appropriately react to environmental challenges and better emotion regulation (Appelhans & Luecken, 2006).

Previous studies that have addressed measures of ANS suggest that both PNS and SNS increase during emotional tasks. EDA, particularly skin conductance (SC), has been shown to increase both during neutral writing and EW (McGuire et al., 2005), suggesting that writing increases SNS activity, regardless of writing topic, in experimental settings. HR has also been found to increase during EW (Sloan et al., 2007), particularly when participants were trained to focus on their response to a traumatic event (Konig et al., 2014).

It has been commonly accepted that higher HRV is linked with better emotion regulation (see Appelhans & Luecken, 2006; Mather & Thayer, 2018). Both SDNN (Seeley et al., 2016) and RSA (Bourassa et al., 2017; Sheerin et al., 2018) have been found to increase after completing an EW task, more specifically when participants wrote coherent narratives (Bourassa et al., 2017). Furthermore, those with higher RSA at baseline benefit the most from EW (Sloan & Epstein, 2005). Finally, a study by Kim et al. (2019) using biofeedback showed that increases in LF/HF activity are associated with greater emotional control.

In this study, we set out to study real-time writing dynamics and ANS activity during EW. We designed a real-time study of EW in which participants were randomly assigned to one of two groups: an expressive group (EG), writing about a traumatic or stressful life experience, and a control group (CG), writing about daily routine. We simultaneously recorded writing and psychophysiological data. Participants in each group were compared on all collected measures. As writing about a trauma is likely to have higher cognitive and emotional load than writing about a daily routine, we anticipated pauses to be longer in the EG. We expected participants in both groups to show increased SNS activation from baseline since both departed from rest to complete a writing task. Due to the heavier load of writing about a traumatic or stressful life event, we expected the EG to show greater SNS (SC) activation when faced with the task. Finally, we expected the EW group to show higher PNS (RMSSD; HF) activation and sympathovagal balance (LF/HF ratio) than the CG, during writing and postwriting (PW), since both are thought to index emotion regulation.

Method

Participants

Fifty-seven participants psychology undergraduates were recruited and randomly assigned to one of two groups: the EG (n = 29; range = 17–51 years, M = 20.1, SD = 6.50; 16% male) or the CG (n = 28; range = 18–39 years, M = 19.9, SD = 4.54; 21.7% male). Participants received course credits for their participation. Estimates of sample size were deemed appropriate by G*Power 3.1 (Faul et al., 2009), as a sample size of 56 participants was estimated to achieve .90 power (f = .30).

Materials

Positive and Negative Affect Schedule

Positive and negative affect schedule (PANAS; Watson et al., 1988; Portuguese version by Galinha & Pais-Ribeiro, 2005) was used to measure mood before and after writing. PANAS has two 10-item mood scales, one positive and one negative. The scales were shown to be internally consistent (positive affect: α = .86; negative affect: α = .89) and not significantly correlated. Each PANAS item is replied using a 5-point Likert scale, and scoring is done by adding the values for the positive and the negative affect scale (min = 10; max = 50).

HandSpy

We used HandSpy 2.3 (Alves et al., 2019) and Neo smartpen M1 (Neo Smartpen Inc., Scotts Valley, CA, USA) to record the written texts and associated writing behaviors. HandSpy was used to measure burst length (number of words), pause duration (ms), number of pauses (pauses threshold was set at 2 s), fluency (words per minute), and burst speed (mm/s).

Writing Topics

Participants in the CG wrote about their daily routine, and participants in the EG wrote about the most traumatic experience of their life. Participants in the EG were free to disclose on any traumatic or stressful life event of their choice. Participants were not selected based on having previously experienced a traumatic or stressful life experience, but every participant had an event to report. This was expected since the prevalence of traumatic experiences is thought to be high in the general population (89.7%; Kilpatrick et al., 2013) and among undergraduates (85%, Frazier et al., 2009). Participants wrote about a variety of experiences, such as domestic violence, problems in romantic relationships, parental divorce, death or a life-threatening moment, bullying or hazing, extreme anxiety, sexual assault, and experience of psychopathology.

EDA and HRV Recordings

Raw EDA and HRV (through ECG) were recorded using, respectively, the Bionomadix BN-PPGED-T (Wireless Photo Plethysmogram and Electrodermal Activity BioNomadix Transmitter) and BN-RSPEC-T (Wireless respiration and ECG Bionomadix transmitter) amplifiers, together with the BN-LOGGER (Bionomadix wireless wearable pshysiology logger), all from Biopac (Biopac Systems, Goleta, CA). Signals were recorded at a sampling rate of 1,000 Hz and filtered using a band pass of 0.5–35 Hz. The EDA measure used for analysis was the mean SC level (the mean EDA value computed across all stimuli; see Dawson et al., 2007). This measure of EDA was chosen as emotion states could be occurring throughout the writing exercise. To clean and divide the raw EDA and ECG data, we used Biopac AcqKnowledge 5.0. The data were divided into 5-minute segments – baseline (B), writing 1 (W1), writing 2 (W2), writing 3 (W3), and PW. Baseline data were collected for 10 minutes, but only the last 5-minute data were used for the analysis. Baseline data were collected at rest to correct for the effects of the writing task on physiological activation (Fichel et al., 2007). EDA data from two participants and ECG data from five participants were excluded from psychophysiological analysis due to artifacts (Pichot et al., 2016). HRVanalysis 1.1 (Pichot et al., 2016) was used to calculate the measures of HRV (SDNN, RMSSD, HF; LF/HF). Raw ECG was exported from Biopac AcqKnowledge 5.0 to HRVanalysis 1.1, where R–R intervals were automatically detected from the raw ECG. From the R–R intervals, the HRV measures were calculated using wavelet transform through local linear analysis (Pichot et al., 2016).

Procedure

Participants started by signing an informed consent and completing the PANAS scale. To record EDA, two electrodes were placed at the medial phalanges of the nondominant hand. To record ECG, three electrodes were placed according to a lead III configuration (see Berntson et al., 2007, p. 184). Following Pennebaker (2002), great care went to creating strict conditions of trustworthiness and confidentiality for collecting the written texts. Participants wrote in a booth and received their confidential instructions in a closed envelope, unbeknownst to the experimenter. As the experimenters were blind to the experimental condition of the participants, random assignment was done by the second author, who shuffled the envelopes containing the confidential instructions. Participants were asked to "sit in a comfortable position, relax, and stay calm, with as little movement as possible for 10 minutes" (baseline), after which they wrote for 15 minutes. The EG was instructed according to a modified version of Pennebaker and Beall's (1986) original EW instructions as follows: "For the next 15 minutes, I would like you to write about your very deepest thoughts and feelings about the most traumatic experience of your entire life. In your writing, I would like you to really let go and explore your very deepest emotions and thoughts. You may tie this event to your past, your present, or your future, or to who you have been, who you would like to be, or who you are now. We guarantee anonymity and confidentiality of everything you write. Don't worry about writing the text correctly. Don't worry about spelling mistakes, sentence structure and grammar. The only important rule is that, from the moment you start writing, you keep writing until you are told the time is up." The CG was given the same instructions, replacing traumatic event with daily routine, and removing any mention to emotions. Upon writing, participants completed PANAS again and were then asked to stay comfortable and relaxed for 5 more minutes. Psychophysiological data were recorded from baseline to the end of PW. All participants were thanked and debriefed at the end of the experiment.

Data Analysis

The control group and EG were compared on PANAS scores, real-time writing measures, mean SC, HR, SDNN, RMSSD, HF, and LF/HF ratio. Outliers were identified through box plot analysis based on the interquartile range (1.5 × IQR) and removed from the database by assigning missing values to the outlier variables (3.7% of all data),[1] as decided a priori. Prewriting and PW PANAS scores of the two groups were analyzed with a mixed-design ANOVA, with the α threshold set at .05. Group differences were tested using independent mixed-design ANOVA conducted for the real-time writing measures (burst length, pause duration, number of pauses, fluency, and burst speed), with *group* (EG, CG) as a between-subjects factor. Mixed-design ANCOVA was independently performed for EDA (mean SC), HR, and each measure of HRV (SDNN, RMSSD, HF, LF/HF), with *group* as a between-subjects factor, *time period*

[1] The data file can be accessed online at https://osf.io/gje24/.

Table 1. Descriptive statistics for collected measures and analysis of variance for between-groups comparisons

	Expressive		Control			
Measures	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*F*	*p*
Positive affect						
Baseline	29	26.24 (6.89)	28	25.61 (5.97)	0.13	.72
Postwriting	29	22.76 (8.80)	28	28.86 (6.60)	8.71	.01
Negative affect						
Baseline	29	13.71 (3.68)	28	13.71 (3.63)	0.00	.96
Postwriting	29	21.71 (9.30)	28	11.25 (1.65)	34.39	.00
Burst length (words)	29	9.93 (3.61)	28	10.20 (3.83)	0.07	.79
Pause duration (ms)	29	4,331.26 (902.79)	28	3,788.63 (753.68)	5.58	.02
Number of pauses	29	34.29 (9.80)	28	32.57 (10.34)	0.41	.53
Fluency (wpm)	29	19.03 (4.39)	28	21.01 (4.56)	2.81	.10
Burst speed (mm/s)	29	35.20 (11.19)	28	33.63 (9.39)	0.32	.58
Skin conductance						
Baseline	28	8.01 (3.36)	27	8.20 (4.79)	0.03	.87
Writing segment 1	28	9.41 (4.14)	27	8.67 (4.21)	1.57	.22
Writing segment 2	28	8.47 (4.37)	27	7.62 (3.90)	0.30	.59
Writing segment 3	28	8.53 (4.58)	27	8.23 (4.59)	0.00	.98
Postwriting	28	9.31 (3.61)	27	9.50 (4.62)	0.00	.97
Heart rate						
Baseline	26	83.85 (12.40)	26	88.10 (11.35)	1.51	.23
Writing segment 1	26	86.42 (10.35)	26	88.29 (10.35)	0.04	.84
Writing segment 2	26	86.17 (11.56)	26	91.66 (12.02)	0.64	.43
Writing segment 3	26	85.57 (11.04)	26	89.07 (9.62)	1.63	.21
Postwriting	26	85.23 (10.24)	26	86.77 (9.34)	0.00	.96
SDNN						
Baseline	26	61.51 (23.70)	26	65.18 (25.95)	0.25	.62
Writing segment 1	26	58.58 (24.89)	26	51.31 (20.90)	1.96	.18
Writing segment 2	26	46.80 (13.47)	26	44.91 (14.67)	0.47	.50
Writing segment 3	26	52.80 (16.27)	26	49.80 (19.59)	2.52	.13
Postwriting	26	81.64 (27.45)	26	76.06 (16.94)	2.10	.16
RMSSD						
Baseline	26	39.77 (16.52)	26	40.31 (18.83)	0.01	.92
Writing segment 1	26	37.84 (24.54)	26	33.87 (11.12)	0.00	.97
Writing segment 2	26	33.08 (14.77)	26	39.54 (21.53)	0.25	.63
Writing segment 3	26	33.60 (12.34)	26	33.88 (12.96)	5.43	.03
Postwriting	26	41.61 (15.85)	26	41.54 (13.35)	0.04	.84
HF						
Baseline	26	610.01 (475.59)	26	549.19 (522.52)	0.17	.68
Writing segment 1	26	470.88 (429.55)	26	346.69 (226.81)	1.49	.23
Writing segment 2	26	404.20 (313.74)	26	279.88 (168.41)	2.35	.14
Writing segment 3	26	348.85 (183.39)	26	318.80 (289.04)	5.71	.03
Postwriting	26	642.82 (473.48)	26	539.32 (324.14)	0.12	.73

(Continued on next page)

Table 1. (Continued)

	Expressive		Control			
Measures	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*F*	*p*
LF/HF						
Baseline	26	2.49 (1.72)	26	2.62 (1.73)	0.07	.80
Writing segment 1	26	1.74 (.87)	26	2.02 (1.64)	1.32	.26
Writing segment 2	26	2.54 (1.41)	26	2.02 (1.14)	1.57	.23
Writing segment 3	26	2.60 (1.15)	26	2.43 (1.92)	5.86	.03
Postwriting	26	2.55 (1.06)	26	2.33 (1.28)	6.84	.02

Note. HF = high frequency; LF = low frequency; RMSSD = root mean square of the successive N–N interval differences; SDNN = *SD* of normal-to-normal (N–N) intervals.

(W1, W2, W3, PW) as a within-subjects factor, and *baseline* values of EDA, HR, and HRV as covariates. As there is a risk of incurring on type I errors (false positives) when testing more than one hypothesis (Chen et al., 2017), all significant results reported below were corrected for multiple comparisons using the false discovery rate (FDR) method (Benjamini & Hochberg, 1995). In this study, all results remained significant after the FDR correction.

Results

Descriptive Statistics

Table 1 displays descriptive statistics, as well as F and p values, for PANAS, real-time writing measures, SC, HR, SDNN, RMSSD, HF, and LF/HF ratio.

Manipulation Check: Effects of EW on Affect

A mixed-design ANOVA revealed an interaction effect of Group × Time period (prewriting; PW) on both positive affect, $F(1, 55) = 14.9$, $p < .001$, $\eta_p^2 = .21$, and negative affect, $F(1, 54) = 33.2$, $p < .001$, $\eta_p^2 = .38$, and a main effect for *time period*, $F(1, 54) = 9.3$, $p = .004$, $\eta_p^2 = .15$. There was also a main effect of *group* on negative affect, $F(1, 54) = 22.0$, $p < .001$, $\eta_p^2 = .29$, with the EG showing higher negative affect after writing.

Group Differences in Real-Time Writing Measures

A one-way ANOVA revealed significant differences between groups in pause duration, $F(1, 51) = 5.58$ $p = .02$, $\eta_p^2 = .10$, with the EG showing longer pauses. No significant differences were found on fluency, $F(1, 56) = 2.81$, $p = .10$, burst length, number of pauses, and burst speed (all $F < 1$).

Indices of SNS Activation

Group Differences in SC (Increased SC Indexes Higher SNS Activation)

The mixed repeated-measures ANCOVA revealed no significant interaction between Group × Time period ($F < 1$). No main effect was found for *group* ($F < 1$), but a main effect of the *time period* was found for SC, $F(2.25, 112) = 8.13$, $p < .001$, $\eta_p^2 = .14$. Pairwise comparisons adjusted for multiple comparisons (Bonferroni) showed that both groups have lower SC in W1 than W2 ($p < .001$), with SC going up again at PW ($p < .001$).

Group Differences in SDNN as a Measure of Overall HRV (Decreased SDNN Indexes Higher SNS Activation)

A mixed-design ANCOVA showed no significant interaction between Group × Time period ($F < 1$). A marginal effect of *group* was found on SDNN, $F(1, 23) = 3.45$, $p = .08$, $\eta_p^2 = .13$, but no main effect was observed for *time period*, $F(3, 69) = 1.80$, $p = .16$.

Indices of PNS Activation

Group Differences in RMSSD (Increased RMSSD Indexes Higher PNS Activation)

The mixed-design ANCOVA showed no significant interaction between Group × Time period, $F(3, 66) = 1.73$, $p = .17$, and no main effects of *group* ($F < 1$) nor *time period*, $F(3, 66) = 2.12$, $p = .11$, on RMSSD.

Group Differences in HF (Increased HF Indexes Higher PNS Activation)

The ANCOVA found no Group × Time period interaction ($F < 1$). No main effect of *group* was found, $F(1, 23) = 2.46$, $p = .13$, but the ANCOVA revealed a main effect of the *time period* on HF, $F(3, 69) = 4.83$, $p = .004$, $\eta_p^2 = .17$. Pairwise comparisons based on adjustment for multiple

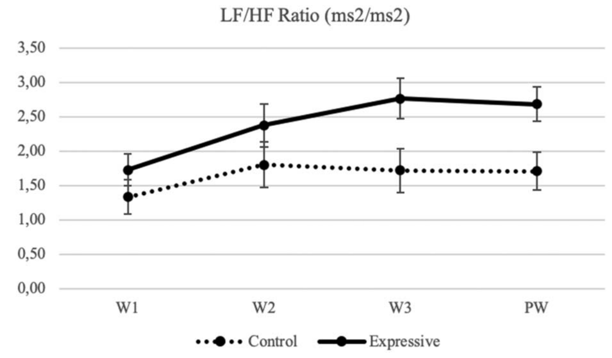

Figure 1. Mean LF/HF ratio scores for each experimental group from the beginning to the end of the writing task and postwriting. Greater values indicate higher LF/HF ratio. Line bars represent standard error of the mean. HF = high frequency; LF = low frequency.

comparisons (Bonferroni) showed that both groups have lower HF in W1 (p = .02) and W3 (p = .004) than PW.

SNS/PNS Activation

Group Differences in HR (SNS/PNS Activation)

The ANCOVA showed no significant Group × Time period interaction ($F < 1$). No main effect was found for *group* ($F < 1$) or *time period*, $F(2, 54) = 1.22$, $p = .35$.

Group Differences in LF/HF Ratio (SNS/PNS Activation)

The ANCOVA revealed no significant Group × Time period interaction, $F(3, 63) = 1.10$, $p = .36$, but showed a main effect of *group*, $F(1, 21) = 5.84$, $p = .03$, $\eta_p^2 = .22$, with the EG displaying higher LF/HF ratio (p = .03; see Figure 1 in Electronic Supplementary Material 1). No main effect was found for time period, $F(3, 63) = 2.04$, $p = .12$.

Discussion

We designed a real-time study of EW to examine writing dynamics associated with emotion regulation and its psychophysiological correlates. We anticipated pauses to be longer in the EG as EW should lead to higher cognitive and emotional load. We also expected participants in both groups to show increased SNS (SC) activation from baseline, since both groups completed a writing task. Finally, due to the emotional load of EW, we expected the EG to show higher PNS (RMSSD; HF) activation and LF/HF ratio than the control, during writing and PW, as indexed through HRV.

Manipulation check results showed that, as expected, negative affect increased in the EW group after completing the EW task. This is in line with all studies of our knowledge conducted within the EW paradigm (Konig et al., 2014; Pennebaker & Beall, 1986; Smyth, 1998). After writing about a traumatic or stressful life event, participants report increased negative affect.

As expected, EW participants paused for longer than those in the CG. Previous studies showed that, in adult writers, pause duration increases when dealing with a secondary task (Fayol, 1999). In this study, the secondary task might have been the emotional load of EW. These findings could mean that pauses are a step to achieve emotion regulation, particularly to make the meaning of the experience. To the best of authors' knowledge, this is the first study of EW that has revealed increased pause duration during writing. Future research should systematically study how different emotion regulation strategies might influence pause duration.

The results show that writing is associated with increased ANS activity. SC results match those shown by McGuire et al. (2005), who found an increase in SC during 15 minutes of writing, for both neutral writing and EW. This is consistent with the temporal dynamics of the ANS systems, since SC increases more slowly than heart rate (Levenson, 2014); therefore, it might not be a sensitive measure to observe SNS differences in real-time.

In our study, HR did not show significant differences between groups. This is in line with Konig et al. (2014) who found the same results when participants were not trained to focus on their emotions beforehand. Another study by Sloan et al. (2007) found an increase in HR after EW. This might be because Sloan et al. (2007) calculated mean HR across 20 minutes and subtracted mean HR at baseline, which we did not do. No significant results were found for SDNN, RMSSD, and HF (RSA) between groups, suggesting that in our study there was no specific sympathetic or parasympathetic activation during EW (W1, W2, W3). Previous studies have found that SDNN increased after EW, but only for participants who previously showed high levels of emotional processing (Seeley et al., 2016). Interestingly, we found higher HF (RSA) after writing in both groups. A previous study has also found an increase in RSA after writing, but only in the EW group (Sheerin et al., 2018). This might be because in Sheerin et al. (2018), RSA data were calculated as logRSA and not HF and in shorter segments (2.5 minutes as opposed to 5 minutes).

As expected, in this study, participants who completed EW showed an increase in the LF/HF ratio during and after the exercise. Previous studies have linked greater HRV to greater emotion regulation (Appelhans & Luecken, 2006), particularly increased LF/HF ratio (Kim et al., 2019). Therefore, during EW, it seems that neither the SNS (SC; SDNN) nor the PNS (RMSSD; HF) dominated, but a balance between the two was established.

The findings of this study should be viewed under four limitations. First, the participants recruited were college students disclosing on a broad range of traumatic or stressful life experiences. This heterogeneity of negative experiences reported could have led to different levels of negative affect and psychophysiological responses. To circumvent this, future studies might choose to narrow the topic of disclosure or recruit participants sharing a common trauma. Second, future studies could recruit community samples, instead of undergraduates, as they might be similar to the general adult population. Third, we did not study which words were used during moments of high psychophysiological arousal. Future studies should explore the linguistic contents produced, specifically if higher LF/HF ratio is associated with longer pauses. Finally, our study found increased LF/HF ratio, which could suggest increased emotional regulation (Kim et al., 2019) during EW, but other indexes, such as SC, HR, SDNN, RMSSD, and HF, did not yield significant differences between groups.

Our findings suggest that during EW, participants pause for longer and sympathovagal balance is higher than when writing about a control topic. The findings from this first study provide evidence favoring EW as an opportunity for emotion regulation.

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