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Effect of expressive and neutral writing on respiratory sinus arrhythmia response over time

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Abstract

Background and Objectives—Parasympathetic activity, as indexed by respiratory sinus arrhythmia (RSA), underlies key aspects of emotional and cognitive self-regulation. Examining time-varying RSA response during expressive writing about trauma may help inform theory about mechanisms of this intervention. The present study investigated changes in RSA during expressive writing.

Methods—Participants (N = 246, M_{age} = 21.5 years, 72% female) were randomly assigned to expressive or neutral writing conditions and wrote for three 20-minute sessions. RSA was measured continuously during the first and third writing session.

Results—Linear mixed model analyses of RSA changes within and across sessions by writing groups found that neutral writers, but not expressive writers, exhibited change in RSA. The overall RSA changes during expressive and neutral writing are consistent with theory about the relationship between cognitive and emotional processing mechanisms and vagal activation.

Limitations—As the present study was not a clinical sample selected on trauma exposure, findings should be considered preliminary. Additionally, engagement of affective and cognitive processes was only hypothesized, as manipulation checks were not performed.

Conclusions—The present study illustrates the benefits of examining changes in RSA over time. Future work with clinical samples should include additional measures and tasks to better define these mechanisms and rule out alternative hypotheses.

Keywords

expressive writing; respiratory sinus arrhythmia; emotional processing; vagal activation

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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1. Introduction

Brief periods of expressive writing about a traumatic event can produce positive effects on physical and mental health (Pennebaker & Beall, 1986; Frattaroli, 2006; Sloan & Marx, 2004), including greater reduction in negative mood and arousal in expressive writers compared to those who wrote about neutral topics (Smyth, Hockemeyer, & Tullouch, 2008; Sloan et al., 2005). A number of mechanisms have been hypothesized to underlie the effects of expressive writing, such as release of physiological and emotional inhibition (Pennebaker, Hughes, & O’Heeron, 1987), cognitive adaptation and meaning-making (Pennebaker & Seagal, 1999), formation of a more organized narrative of the event (Smyth, True, & Souto, 2001), or exposure to previously avoided thoughts and feelings (Sloan & Marx, 2004a, 2004b; Sloan, Marx, & Epstein, 2005). Understanding the physiological response during expressive writing may help inform theory about the processes at work in this intervention. For example, increases in heart rate (HR) during expressive writing, and the association between these increases and positive outcomes, have been taken as evidence for exposure to feared material as a mechanism of action (Epstein et al., 2005; Author et al., 2014). However, while exposure to feared material is assumed to result in HR increase due to activation of the sympathetic branch of the autonomic nervous system, HR increase can also be caused by parasympathetic withdrawal (Berntson, Cacioppo, & Quigley, 1991). Sympathetic cardiac activation and parasympathetic, vagal activation work independently and simultaneously to foster homeostasis (Sack et al., 2004). Parasympathetic (i.e., vagal) activity may be more closely related to cognitive and emotional regulation (Thayer et al., 2009) but have yet to be examined during expressive writing.

Parasympathetic activity, as indexed by respiratory sinus arrhythmia (RSA), underlies key aspects of emotional and cognitive self-regulation (Thayer & Lane, 2000). The neurovisceral integration theory (Thayer & Lane, 2000) proposes a unifying framework that links vagal activity to cognitive, emotional, and physiological regulation. While resting levels of parasympathetic activity provide a marker of tonic parasympathetic influence and one’s general capacity to self-regulate, phasic changes reflect cognitive and emotional self-regulatory effort (Smith et al., 2011). For example, women instructed to regulate their emotion during a conversation about a negative topic exhibited increases in RSA, whereas no change was found in women given no instruction (Butler, Wilhelm, & Gross, 2006). On the other hand, people instructed to worry exhibit reduced RSA (Thayer, Friedman, & Borkovec, 1996) and attenuated increases in negative affect and arousal as compared to distraction (Skodzik et al., 2016). Furthermore, RSA and related metrics have been frequently associated with cognitive and affective processes, ranging from accuracy and cognitive control during a go/no-go inhibition task following emotion induction (Chapman et al., 2010) to increasing cognitive load during decision making tasks (Zhou et al., 2017) and serial subtraction (Kennedy & Scholey, 2000).

These findings suggest that examining changes in RSA over the course of writing may be useful for identifying and understanding changes in self-regulatory ability during expressive writing, which might in turn be associated with positive outcomes. However, the effect of expressive writing on RSA changes over time has not been examined, particularly over the course of the writing task. Although short-term decreases in parasympathetic activity are

often common during psychological stress (Berntson, Cacioppo, & Quigley, 1993), efforts to regulate emotion and behavior evoke short-term increases (Smith et al., 2011). These patterns of response suggest the importance of assessing RSA changes across time. This study investigated changes in RSA during writing about either a traumatic (expressive writing) or neutral (neutral writing) event, both within and across writing sessions, to help understand the mechanisms involved in expressive writing. Greater change in RSA was hypothesized for the expressive writing group.

2. Materials and Method

2.1 Design

Participants were randomly assigned to one of two conditions, expressive writing and neutral writing. The present study represents a secondary analysis of a study (see Author et al., 2014) that aimed to examine whether training to write as if one were actually in the situations being described would enhance both physiological response to writing and the benefits of written emotional disclosure. Thus participants were assigned to one of three training conditions adapted from studies of emotional imagery processing (Lang, Kozak, Miller, Levin, & McLean, 1980, Lang, Levin, Miller, & Kozak, 1983): response training (providing descriptions of physiological and behavioral experiences; e.g., “my heart is racing”), stimulus training (providing descriptions focusing on sensory detail; e.g., “the sun is shining”), and no training¹. Although response training was associated with the greatest heart rate increase during writing in the original study, there was no effect of training condition on RSA across the writing period ($p=.57$) or sessions ($p=.74$). Given the aims of the present study, to examine RSA as a function of expressive writing overall, these groups are collapsed for the present analyses. Participants wrote for three 20-minute sessions in a laboratory setting, at least one day apart and completed within two weeks’ time. The university’s Institutional Review Board approved all study procedures. Participants were compensated with course credit.

2.2 Participants

Participants were 246 college students 18 years of age or older from a large, urban university Department of Psychology research pool. While participants were not selected for trauma exposure, all were asked to identify the most traumatic/distressing event of their lives, and this event served as the writing topic for the expressive writing group.

2.3 Apparatus and Materials

2.3.1 Physiological assessment—Physiological responses were assessed at sessions one and three, which occurred in the same laboratory space. The electrocardiograph (EKG) signal was recorded continuously throughout baseline and writing periods. The signal was obtained using sensors attached below the right clavicle and lowest left rib in order to reduce movement artifact associated with writing. A ground electrode was placed on the forearm of the non-dominant hand.

¹Additional information about training procedures can be found in Author et al. (2014).

2.4 Procedures

Upon arrival to the first session, participants read and signed the consent form. Physiological sensors were attached and participants were instructed to sit quietly while baseline physiological data were recorded for 10 minutes. Immediately following, they were instructed to write for 20 minutes about either a personal trauma or a neutral topic. To reduce participant time burden, physiological data were not collected at session 2.

2.4.1 Writing Conditions—Writing instructions were adapted from Pennebaker (1997). Expressive writing participants (N=113) were asked to write about “the most traumatic, upsetting experience of your entire life” with as much emotion and feeling as possible. Participants in the expressive writing condition wrote about the same event in each writing session, shown to result in the greatest physiological reactivity (Sloan et al., 2005). Neutral writing participants (N=133) were asked to write without describing any emotion or opinions about “what you did yesterday from the time you got up until the time you went to bed” in session one, “what you did today” in session two, and “what you will be doing over the next week” in session three.

2.5 Data Preparation and Analytic Plan

Given the importance of reducing noise in the physiological signals, each interbeat interval (IBI) series was hand-screened in order to detect and correct any artifacts that were present, and then entered into CMetX (Allen et al., 2007) for calculation of RSA. IBIs were converted to a time series sampled at 10 Hz. The series was then filtered through a 241-point optimal finite impulse response digital filter with half-amplitude frequencies of 0.12-0.4 Hz. CMetX took the natural log of the variance of the filtered waveform as the estimate of logRSA (Allen et al., 2007). LogRSA was calculated for four 2.5-minute segments during the 10-minute baseline and eight 2.5-minute segments during the 20-minute writing period (see Table 1). Change scores were created for RSA by subtracting the final 2.5 minutes of pre-writing baseline from the RSA at each writing period, so positive values indicate RSA increase from baseline during writing. RSA was examined as the change from baseline in 2.5-minute segments across the 20-minute writing period. Data for the final segment in each writing session were excluded from analyses to account for missing data and variable time participants stopped writing.

Linear mixed effects models (LMM) were constructed in SPSS v. 24 (Armonk, NY: IBM Corp., 2016) with maximum likelihood estimation for missing data to investigate the change in RSA values at each measurement segment. Predictors were mean-centered and entered as fixed effects in the models. The initial model included all factors of interest: writing group, sessions (1 and 3), linear and quadratic effects for segment (time). Then, interaction terms were added to test the hypothesis that expressive writing would result in increased RSA as a function of session and writing group. The best fitting models and covariance structures were chosen based on the $-2 \log$ likelihood ($-2LL$), smaller-is-better criterion. Models were built by first including only the fixed effects of all covariates and their interactions and a random effect for the subject variable. Random effects were then added followed by repeated measures effects (West et al., 2014). The final model included a random effect for session (variance components covariance) and residual effects for session and segment

(diagonal covariance). LMMs have utility with clustered and repeated measures (Boisgontier & Cheval, 2016) and are able to handle missing data in the dependent variable (Peters et al., 2012); thus, no multiple imputations occurred prior to analyses. Tests were two-tailed, with a p-value threshold of .05 considered as statistical significance.

3. Results

Descriptive and clinical characteristics are presented in Table 1. The expressive and neutral writing groups did not differ on age ($p=.13$) or gender ($p=.29$). Baseline RSA did not differ between the writing groups ($p=.87$, $p=.35$, session 1 and 3, respectively). Baseline RSA scores decreased from session 1 to session 3 ($p=.01$) but did not differ as a function of writing group (interaction $p=.97$).

As illustrated in Figure 1, overall RSA decreased from baseline to the writing period. Following the initial reduction in RSA below baseline at the start of writing, in the initial model, main effects indicate an increase in RSA over time (linear, $b=.01$, $SE=.004$, $t=2.75$, $p=.006$; quadratic, $b=.01$, $SE=.002$, $t=3.03$, $p=.003$). No effects were seen for writing group ($p=.13$) or session ($p=.65$). The model including these predictors and all interactions converged and all interactions and random effects were retained. Figure 1 shows the overall pattern of RSA change during writing for writing groups across time and sessions. The main effects remained and were subsumed by a three-way writing group x segment (linear) x session interaction, $b=-.04$, $SE=.02$, $t=-2.13$, $p=.03$. To further examine this interaction, the segment x session interaction was examined separately for neutral and expressive writers. Significant segment (linear) x session interactions were found for both groups, with a decrease in RSA across session 1 and an increase in session 3, but the effect was stronger in neutral writers, $b=-.06$, $SE=.01$, $t=-4.54$, $p<.001$, as compared to expressive writers, $b=-.02$, $SE=.01$, $t=-2.29$, $p=.042$.

4. Discussion

In this study, RSA initially decreased from baseline to writing, indicating that the heart rate increase reported while writing in this study (Author et al., 2014) may partially reflect withdrawal of parasympathetic inhibition (Berntson, Cacioppo, & Quigley, 1993). This was true for both expressive and neutral writing, and is consistent with a view of writing as a cognitively-effortful task (Duschek et al., 2009; Hansen et al., 2004). The subsequent increase in RSA is consistent with existing work demonstrating increases in RSA when individuals are making efforts to self-regulate (e.g., Butler et al., 2006; Chapman et al., 2010). The segment x session interaction seen in each group illustrated that RSA decreased slightly across session 1, and increased only in session 3, possibly reflecting that by session 3 participants were engaging in more cognitive and/or emotional self-regulation during writing.

The effects described above were more evident for neutral than expressive writers. For example, in session 1, RSA decreased more for neutral than expressive writers. This may suggest an opponent process by which people writing about distressing, as compared to neutral, topics make efforts toward cognitive and emotional self-regulation, which is

associated with RSA increases (Denson et al., 2011). This would be a more compelling hypothesis if RSA had evidenced a significant increase specific to the expressive writing group in session 1. Instead, the expressive writing group showed less change in RSA compared to the neutral writing group. The possibility that RSA would have continued to increase across a longer session or additional sessions could not be evaluated in the present study and is worthy of future investigation. This lack of RSA increase in expressive compared to neutral writers may have been in part due to the fact that our sample was unselected for trauma-related distress. Many of the expressive writers may have been accessing a relatively inconsequential memory, necessitating greater cognitive effort (and thus vagal withdrawal) to organize a coherent narrative, while neutral writers were activating recent memories or generating easily-accessible plans. By session 3 reduced cognitive effort involved in writing became evident in greater RSA increases across the session for neutral compared to expressive writers. Alternatively, the task may have inadvertently required neutral writers to engage in a form of emotional suppression to avoid writing about an emotional event, thereby triggering vagal activation.

Although increased HR during expressive writing, and the connection between greater HR and better outcome, have been taken as evidence that writing about trauma is a form of exposure (Author et al., 2014; Wisco et al., 2016), an alternative conceptualization is that HR increase during expressive writing at least in part indicates parasympathetic withdrawal, and the subsequent habituation of HR is a sign of parasympathetic return, self-regulatory effort, and cognitive/emotional adaptation. This suggests the mechanisms of expressive writing involve cognitive adaptation and meaning making (Pennebaker & Seagal, 1999; Schweizer et al., 2017), or forming a more organized and coherent narrative of events (Smyth, True, & Souto, 2001). These are not mutually-exclusive hypotheses; examination of the mechanisms at work in trauma writing should incorporate both cognitive and emotional regulation and processing.

Several limitations and important future directions are worth note. Although our instructions were to write until the end of the 20-minute period, we did not monitor compliance and anticipate that some participants finished before they were told to stop. Because we were most interested in the cognitive and emotional processes involved in expressive writing, we attempted to reduce the variability in stop times by excluding the final 2.5 minute segment of data. However, it is unknown whether important patterns of signal evident in the final moments of writing were missed by truncating the data. The present study employed an unselected sample; in the future studies examining clinical populations with traumatic experiences and/or with diagnosed trauma-related conditions will expand understanding of the effects of parasympathetic changes during expressive writing and their association with psychological outcomes, as difficulties regulating emotions have been linked to heightened posttraumatic stress symptoms (Badour & Feldner, 2013; Shepherd & Wild, 2014). Larger samples and longer or additional writing sessions are needed to further examine this relationship. Finally, although we hypothesized cognitive and affective mechanisms based on phasic RSA changes, these hypotheses are speculative, and future work should include additional measures and tasks to better define these mechanisms and rule out alternative hypotheses. For example, assessment of other physiological variables (e.g., skin conductance, salivary cortisol and alpha amylase) in conjunction with RSA would allow for

further specification of the mechanisms underlying emotional processing during this task. Manipulation checks can verify engagement of affective and cognitive processes, such as cognitive reappraisal.

4.1 Conclusions

In conclusion, although other studies have examined baseline RSA as a moderator of the psychological effects of expressive writing (Allen et al., 2007; Sloan & Epstein, 2005), to our knowledge, this is the first to examine phasic RSA as an index of cognitive and emotional processes involved in expressive writing in this manner. The current study illustrates the benefits of examining changes in RSA over the course of cognitive and emotional processing (Luque-Casado et al., 2016). Whereas static, single measures of RSA during the writing period would have shown the expected parasympathetic withdrawal, repeated measures revealed an important pattern of parasympathetic reinstatement as writing progressed. Better understanding of physiological changes during tasks such as expressive writing that attempt to target emotional avoidance and enhance processing (Hauschildt et al., 2011) can inform trauma-relevant treatments. In clinical settings, expressive writing has been used as a standalone treatment (e.g., van Emmerik, Reijntjes, & Kamphuis, 2013) and a component of trauma-focused treatments (e.g., Resick et al., 2008). Findings illustrate that physiological indices can provide information about potential mechanisms underlying psychological interventions. Findings also suggest the benefit of considering psychophysiological responding and adaptability in the context of cognitive and affective approaches inherent in a therapeutic setting for trauma-exposed populations, as potential markers of treatment engagement, progress, and outcome (e.g., Clamor, Koenig, Thayer, & Lincoln, 2016).

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Highlights

- Changes in RSA underlie emotional and cognitive self-regulation
- Neutral and expressive writing resulted in an RSA decrease from baseline to writing
- Neutral writers showed a greater increase in RSA over time while writing
- Repeated measures of RSA revealed a pattern of parasympathetic reinstatement

Figure 1.

Figure 1(a). Mean RSA change scores across writing periods at session 1 and 3 for neutral writers. Significant interaction of session and segment found with a significant linear trend at session 3. *Figure 1(b).* Mean RSA change scores across writing periods at session 1 and 3 for expressive writers. No significant interaction of session and segment found. Note: values represent change scores that are not covariate-adjusted.

Table 1

Group means and frequencies of age, gender, ethnicity, trauma endorsements, and raw RSA at each time point.

	Full Sample (N=246)	Neutral writers (n=133)	Expressive writers (n=113)
Age Mean (SD)	21.49(5.45)	21.12 (4.33)	21.91 (6.52)
Gender (% Female)	72	69.2	75.2
Race/Ethnicity			
White	48	45.1	51.3
African American	28	31.6	23.9
Asian	11	12.8	8.8
Hispanic	2	1.5	2.7
Other	11	9.1	13.3
Log RSA Scores, Session 1			
Baseline	6.36 (1.14)	6.49 (1.14)	6.22 (1.12)
Segment 1	5.96 (1.24)	6.07 (1.68)	5.83 (1.21)
Segment 2	5.80 (1.51)	5.89 (1.71)	5.69 (1.24)
Segment 3	5.77 (1.36)	5.87 (1.48)	5.67 (1.19)
Segment 4	5.85 (1.48)	5.94 (1.68)	5.74 (1.18)
Segment 5	5.81 (1.53)	5.87 (1.74)	5.74 (1.23)
Segment 6	5.87 (1.52)	5.92 (1.75)	5.80 (1.21)
Segment 7	5.88 (1.52)	5.94 (1.72)	5.81 (1.23)
Log RSA Scores, Session 3			
Baseline	6.12 (1.24)	6.20 (1.23)	6.03 (1.24)
Segment 1	5.48 (1.35)	5.46 (1.37)	5.51 (1.33)
Segment 2	5.44 (1.32)	5.43 (1.35)	5.45 (1.28)
Segment 3	5.48 (1.30)	5.48 (1.34)	5.47 (1.25)
Segment 4	5.55 (1.27)	5.54 (1.34)	5.57 (1.18)
Segment 5	5.57 (1.26)	5.56 (1.23)	5.59 (1.31)
Segment 6	5.57 (1.31)	5.60 (1.31)	5.54 (1.31)
Segment 7	5.69 (1.33)	5.74 (1.33)	5.64 (1.33)
Most Common Trauma/Stressful Events			
Death/serious injury of a loved one	53 (22%)	27 (20%)	26 (23%)
Physical or sexual abuse/assault/harassment	20 (8%)	12 (9%)	8 (7%)